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# THE ELECTRIC JOURNAL



THE ELECTRIC JOURNAL is published by The Electric Club. The Journal is unique in having the support of an active electrical society which numbers among its members the engineers of a large electric company, as the club is composed principally of men connected with the Westinghouse Electric & Manufacturing Company.

The aim of the Journal is to be direct, definite and practical, and to be recognized by progressive electrical men as one of the indispensable aids to effective engineering work.

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THE
# ELECTRIC JOURNAL

VOL. IV. JANUARY, 1907 NO. 1.

**The Journal for 1907**

This number opens the fourth volume of THE ELECTRIC JOURNAL. A review of the editorial statements of aims and purposes issued at the beginning of each of the preceding years shows that they would be appropriate now for the coming year. The ideal is still the same; the JOURNAL, too, aims to be the same,—but better.

The initial paragraph of three years ago describes a condition to which the JOURNAL owes much of its strength. It characterizes the engineering apprenticeship course as an educational institution with hundreds of graduate students; with manufacturing and testing departments which correspond to great laboratories; with officers and engineers of a great company, corresponding, in a way, to a faculty, with the result that "the engineering apprenticeship course, supplemented by the Electric Club, is doing more for the advancement of electrical engineering education in this country than any single university or technical school."

The JOURNAL has been a logical development of the work of the Electric Club. It has had a field of its own. As its subject matter, it has the vital, the up-to-date, the active things which concern the electrical engineer; as its writers, it has men ranging in position from apprentices to engineers in the most important positions, all are workers, and many of them rarely or never write except for its pages; as its readers, it has not only the young men of the Electric Club but many thousands of others, widely scattered and connected in various ways with electrical engineering, who have a common interest in the new things, the new methods and the new spirit, which are the basis of present progress.

To be of use to its readers; to be of real assistance to electrical engineers, present and future, and to be an active force in accelerating the progress and advancing the best interests of the electrical engineering profession,—these are the aims and ambitions with which we enter the New Year.

THE PUBLICATION COMMITTEE

**Corrective Effects**

A perusal of the article on "Niagara Power at the Lackawanna Steel Plant," by Mr. John C. Parker, which appears on another page of this issue, indicates that in the design of that plant considerable importance was attached to the ability of synchronous apparatus to correct for low power-factor of load. This fact simply emphasizes this peculiarity of the alternating-current system. An alternating-current circuit requires—if we may put it that way—a certain amount of magnetism which must be supplied from synchronous machines. The higher the voltage and the lower the power-factor of a given load, the greater must be this amount of magnetism. The amount of magnetism required in a given case may be measured by the so-called "wattless component." An induction motor, for instance, taking 80 real kw at 80 per cent power-factor, takes from the circuit a total of 100 k.v.a. of which the wattless component is 60 k.v.a. In other words we may say that that motor takes 60 k.v.a. of magnetism, which must come from some synchronous apparatus. At the Lackawanna Steel Company's plant, for instance, were it not for their over-excited synchronous apparatus, this 60 k.v.a. of magnetism would have to be put into the system by the generators at Niagara Falls, thence transmitted through the various transformers and transmission lines until utilized by the motor we have assumed. The synchronous apparatus they have installed however, makes it possible to put in at least a part of the required magnetism close to the point needed. As long as synchronous apparatus operates at a lagging power-factor it is receiving a part of its magnetism from some outside source. At unity power-factor it is just supplying its own needs. As soon as its field magnetism is forced above this point it generates, so to speak, an excess of magnetism which becomes available for neutralizing the lagging wattless component of induction motors and similar apparatus. The magnetism thus generated at the Lackawanna plant reduces by just so much that necessary at Niagara Falls. Further it makes it unnecessary to transmit from Niagara Falls so much of the wattless component as the over-excitation of the synchronous apparatus is able to neutralize.

There is nothing new in this thought; it simply treats the matter of wattless components and power-factor in alternating-current circuits from the standpoint of the generation of magnetism,—if we may be allowed to use such a term. Making use of this term, the following propositions are obvious:

(1) Every alternating current circuit requires the generation of a certain amount of magnetism.

(2) This magnetism may be put into the circuit by any piece of synchronous apparatus; generator, motor or rotary converter.

(3) Induction motors or other apparatus taking lagging current, require magnetism to be put into the circuit at some point.

(4) The amount of magnetism required by an alternating-current circuit, increases as the power-factor decreases and is proportional to the wattless component.

P. M. Lincoln

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**Transformers at the Lackawanna Steel Plant**

The modern transformer is simple, rugged and reliable. It stands at the fore in transmission work like the turbo-generator in the central station. Two factors, the enormous power developments requiring transmission apparatus, and improvements in material, have stimulated the design and made possible the construction of transformer units which for size, voltage, performance, simplicity and rugged reliability were barely thought of even two years ago.

The design of an up-to-date high tension transformer station handling several thousand kilowatts and controlling the supply of electricity to large and important industries and communities, is a problem requiring the same engineering skill and judgment as the power house layout. Reliability, simplicity, flexibility and economy are the usual guides in this work.

A thoroughly modern transformer installation is described in the article by Mr. Parker on the "Niagara Power at the Lackawanna Steel Plant," and represents up-to-date practice and engineering judgment where continuity of service, economy and general reliability are of the utmost importance. The decision to install "fool proof and straightforward" apparatus is fully in accord with present tendencies as exemplified in the transformer design with their strong boiler iron fire-proof tanks.

The simple high tension winding, the transfer truck instead of a crane, the omission of barriers between or pits for the transformer units, the oil piping system and the duct structure between the stations as described, all make for the simplicity of the installation. The control of the power-factor and the equalizing of the load between the local plant and the transmission line through synchronous motor-generator sets is a novel and interesting application.

K. C. Randall

**Railway Signaling**

The development in this country of signaling for railroads has covered a period of about forty years, but not until the last ten years has any great impetus been given to this line of business. Steam railroad companies, the most conservative of corporations, have, until recently, looked upon railroad signaling as in the nature of insurance, something rather to be endured than otherwise. But gradually it has become evident that the signaling of a road was necessary from an economical standpoint, as it not only reduced the number of wrecks and consequent loss of life, but it also greatly facilitated the handling of trains, allowing the maximum number of trains to operate within a given length of road with the maximum amount of safety. In fact, a signal system for a road with heavy traffic, is planned with the maximum braking distance as the controlling feature. This feature was carried out on the Interborough Rapid Transit Company's lines in the New York subway. The blocks in the subway were made 800 feet long, 100 per cent being added to the maximum braking distance (400 ft.) to cover slippery rail conditions, etc.

The telegraph block system was the first to come into extensive use in railroad block signaling. When using this system the road is divided into sections from one to five miles or more in length. A telegraph operator controls the passage of trains into each block by means of signals operated manually or otherwise. Later, the automatic block signal system, in which the signals are controlled by the trains themselves, came into service. This system is now in extensive use and bids fair to assume mammoth proportions as it is not expensive to maintain, and obviates any error due to the failure of memory or the non-attendance to duty of an operator.

One of the great obstacles to the adoption of automatic block signaling has been the large outlay required for the installation of the apparatus, which on the great trunk lines spanning the continent reached an enormous sum. This apparently high first cost has recently lost its discouraging aspect and automatic block signaling is being very generally installed.

The introduction of electric traction has made signaling a necessity, as on roads of this character it is necessary to operate the trains at high speed and with the maximum headway. The growth of large cities has also materially advanced the signaling business as they require large railroad terminals which in turn require a quick and safe means of controlling trains entering and leaving the terminals. It became obvious that some means other than dependence upon

human memory was necessary and so a system for the automatic interlocking of switches and signals was designed. With an interlocking system it is impossible for the operator to make a false movement, thereby bringing two trains together.

The article in this issue by Mr. T. Geo. Willson, which is the first of a series of articles on this subject, clearly shows the principles involved in mechanical interlocking, which is one of the forms of signaling used on steam and electric railroads.

The art of signaling, if such it may be called, has grown from the small signal operated by hand power, to the present automatic signal systems on our high speed electric roads, and the elaborate systems of interlocking with their numerous levers and rods which control a thousand trains a day in and out of the large railroad terminals. The first system of interlocking for controlling trains over railroad crossings was what is known as mechanical interlocking. This system involved the operating of the switches and signals by hand power and mechanical apparatus. As the size of the territory to be covered by an interlocking tower grew, it became necessary to devise some means of operating switches and signals over a greater area than was possible by hand power; therefore, what is known as the electro-pneumatic system was devised. This system operates the switches and signals by fluid pressure and the control and indication of the position of the switches and signals by electric power.

The newest system of interlocking is what is known as the all-electric system, in which, as the name implies, electric power is used for all purposes. Electric motors operate the switches and signals, and the indications and control are also electrical. All three systems have their particular field of operation and all are extensively used.

L. H. Thullen

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**Correspondence Departments**

The address of Mr. H. D. Shute, assistant to the second vice-president, made to the Electric Club on November 26, 1906, on the subject "The Correspondence Departments of the Electric Company," and which is reproduced in this number of the Journal, can be read with profit by the large majority of subscribers. The Journal has on its subscription list a large number of customers of the Electric Company, many of whom will learn for the first time of the policy of the company with regard to its selling (district) offices. A knowledge of this policy will naturally prompt an effort to follow it and as a result not only will the co-operation of the Electric Com-

pany's customers be secured towards making that policy a success, but the customers will benefit because they will obtain better service.

Possibly the greatest benefit from the address will be derived by the individual correspondents themselves. Mr. Shute modestly, as becoming his nature, refrained from speaking of his own advancement through the medium of the correspondence department. Possibly, however, the individual correspondents will be otherwise sufficiently impressed by the address, as to their opportunities. It is fair to assume that they already had a more or less complete knowledge of their responsibilities, but certainly Mr. Shute makes plain that their lives are strenuous lives—a drone would have little chance in such a busy hive. It would be interesting to see a schedule of the members of the different correspondence departments who have "come and gone" during the past fifteen years, and of the waiting list of applicants. It is to be hoped no names will be withdrawn from the latter as a result of a complete knowledge of what is expected of a correspondent. However, the opportunities, and these are known quantities, will hold the men who can "get things done," At the same time the men who will advance will give less immediate thought to their opportunities and more to their duties.

James C. Bennett

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Mr. John Hays Smith, who has been connected with this Journal from its beginning—first as Business Manager and then as Manager—has withdrawn from the Journal and is now in charge of *The Eleectrical Age*, of New York. The Journal wishes Mr. Smith the best of success in his new field. *The Electrical Age* will greatly profit if Mr. Smith gives to it the enthusiasm and energy which has contributed so largely to the success of this Journal.

Mr. A. H. McIntire, the Editor of the Journal, has been added to the Publication Committee, and has been made Editor and Acting Manager.

# RAILWAY SIGNALING—I

## MECHANICAL INTERLOCKING

T. GEO. WILLSON

THE essential elements of an interlocking plant consist, in general, of a group of levers concentrated at a central point for operating certain switches and signals, and so arranged as to interlock such levers and make it impossible to give clear signals for conflicting routes. The advantages derived therefrom are safety, facility of operation and saving in cost of manual labor employed.

It is the purpose of this article to give, as briefly as possible, a general outline of what is accomplished by interlocking, the manner in which the work is done, and the construction of a particular type of machine.

### TYPES OF MACHINES

As has been intimated, various types are in use, and they may be divided into classes as follows: Mechanical, hydro-pneumatic, electro-pneumatic, pneumatic, and electric.

Each style of machine is known by the kind of power utilized to perform the various functions for which it was designed, and as all were designed for the purpose of doing a certain kind of work, a description of the original (mechanical) machine, will give not only the method of operation peculiar to itself, but also a general idea of the principle of interlocking as used in all machines.

An interlocking machine may be small in size, that is, may have but few levers, sufficient to properly protect a single track grade crossing; or it may be to take care of a crossover between the tracks of a double track road; or to protect a junction point where two single track roads converge. Or, on the other hand, the machine may be a large one, with many levers, sufficient to properly handle a grade crossing where several roads cross other roads, and perhaps having interchange tracks; or, it may be for handling a large classification yard, a large passenger terminal, or a combination of any of the above. Therefore, the size of machine depends entirely upon the arrangement of tracks at the point to be protected.

### METHOD OF SIGNALING A PLAN OF TRACKS

When it is desired to install an interlocking plant, the first thing is to have a plan of tracks, which is then signalled up, that is, all

the switches to be operated are noted; the derails, signals, tower, and run of connections are located; the size of machine and func-

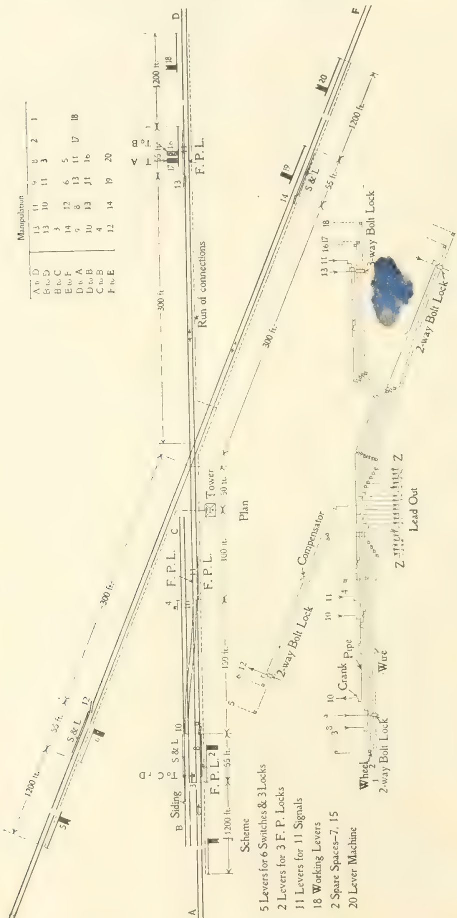



FIG. 1—TYPICAL RAILROAD CROSSING PROTECTED BY A MECHANICAL INTERLOCKING PLANT

tions of each lever are determined; and a diagram of the leadout made, as illustrated by Fig. 1. From the signalled plan, a locking

sheet is then made, that is, the proper interlocking to be done between levers is determined, as illustrated by the locking sheet in Fig. 5. From the locking sheet, a dog sheet is made, this being a diagram which shows the arrangement of the interlocking parts as they are to be placed in the machine. This is illustrated by the dog sheet in Fig. 5.

The plan, as shown on Fig. 1, is a typical layout of tracks, showing a grade crossing protected by derails, and a siding connected with one of the main tracks by a crossover. At each switch or derail a signal is located to govern movements over the point where the tracks intersect. The numbers shown at each switch, derail, signal, etc., mean that that particular switch, derail, signal, etc., is to be operated by a lever having the same number in the machine. That is, lever *1* will control signal *1*, lever *9* derail *9*, etc. By referring to the scheme, it will be found that eighteen levers will be required to operate this plant, but as mechanical machines are built up of four lever sections, a machine will be used having eighteen working levers and two spare spaces, the latter being available for levers in case it be necessary to make an addition to the plant at some future time.

When no movements are being made over the crossing, all derails are open, the switch on the siding set for the stub end, and all signals are in the horizontal (danger; stop) position, and when in such position, they are known as being *normal* and the levers in the machine are normal also. When a derail is closed, a switch thrown, or a signal cleared, they are then known as being in the *reverse* position, and the lever by which the operation is performed is then also known as being in the reverse position.

When a movement is desired over any one of the tracks, it is necessary to set all switches and derails in the right position for such movement, then lock them in such position, after which the signal governing traffic over that particular track may be cleared. Under the head of "*Manipulation*" in Fig. 1, is a table showing just what levers are to be reversed to allow movements over the various routes. For example, in order to allow a train to go from *A* to *D*, levers *13-11-9-8-2* and *1* must be reversed in the order named, and the last lever reversed locks all of the preceding ones. The closing of either derail in the route will lock the derails of conflicting routes normal, they in turn will hold the signals normal. Therefore it will be seen that where two or more routes conflict, the signals of but one can be cleared.

### SWITCHES AND DERAILS

A switch is used to deflect traffic from one track to another. A derail is in reality a switch, and is also used for deflecting traffic, but not from one track to another, for as its name implies, its purpose is to derail, or deflect from the rails onto the ties, or ground, or into some short track or obstruction, in order to stop traffic if the signal be disregarded. Nos. *9-12-13-14* in Fig. 1 represent derails. They operate in such a way that if, for any reason, an engineer attempts to take his train over a crossing when the signal governing the movement is normal (stop) his train will be derailed, and as the derails are located 300 feet from the crossing, the train would not reach the tracks of the other road, (which may be occupied by another train) even though it may have been moving at high speed before leaving the rails. Although derails will accomplish this, it is not expected or desired that this should occur, and it very rarely happens for the reason that, if an engineer knows his train will be derailed if he attempts to pass a signal at danger, he will be very careful to stop at the signal.

### THE DETECTOR BAR

At each switch is a bar which lies against the outside of the rail, and is so adjusted that the top of the bar, when in the normal position, is three-eighths of an inch below the top of the rail. This is what is known as a detector bar, and works in conjunction with the lock on a switch, so that when a movement is being made over a switch, the wheels will prevent the bar from being raised, thus preventing the leverman from unlocking the switch when a train is passing over it. Before a train movement can be made all switches, after having been set in the proper position, must be locked. This is done by a bolt or dog being thrust through a notch or hole in a bar connected to the points of the switch. If for any reason the switch points do not go to the proper place when the lever by which the switch is operated is thrown, it is obvious that the bolt or dog cannot be thrust through the bar and the switch cannot be locked, thus indicating to the leverman that the switch is not in proper position.

### METHOD OF LOCKING SWITCHES AND DERAILS

A switch may be moved and also locked by a single lever. When this is done, a mechanism called a switch and lock movement is used,

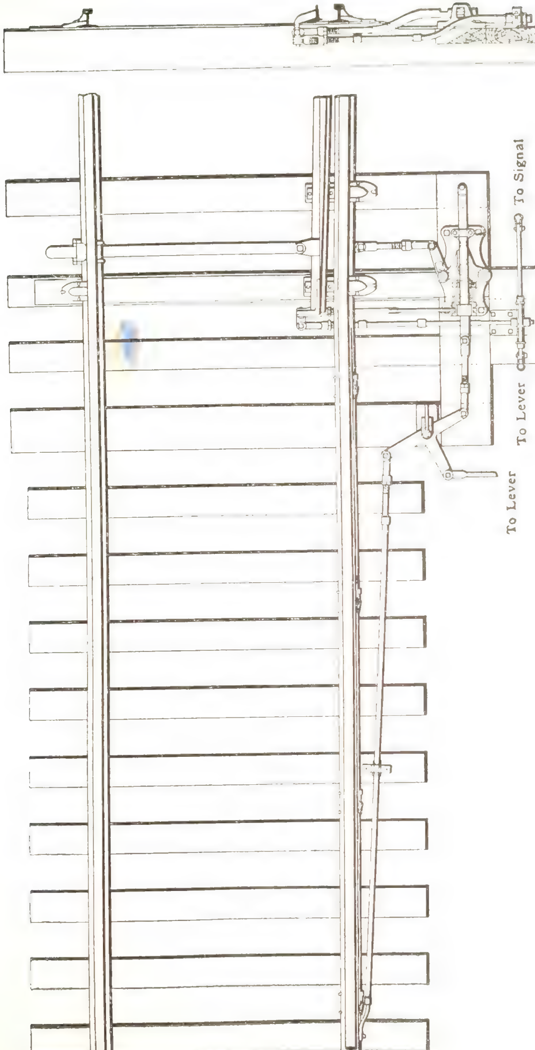



FIG. 2—SWITCH AND LOCK MOVEMENT WITH BOLT LOCK APPLIED TO DERAIL

it being located opposite the switch. When actuated by a lever in the machine, the first part of the stroke unlocks the switch, the mid-stroke throws it, and the last part of the stroke locks it. Thus the switch is locked either normal or reversed, depending upon the position of the lever. When such a device is used, on main tracks, the signals governing movements over such tracks are also made to lock the switch by means of what is called a bolt lock, which makes it impossible for a signal to be cleared if for any reason the switch is not in the proper position. Fig. 2 illustrates a switch and lock movement with bolt lock applied to a derail.

While some roads use switch and lock movements on main tracks, most roads use them only for the siding end of cross-overs, or for derails on unimportant sidings, preferring the use of a separate lever to operate the locks on main line switches. When a separate lever is used, the lock is called a facing point lock, getting its name from the fact that originally a switch was locked only when traffic was to be given the right of way in the direction facing the switch point, but present practice is to lock all switches whether traffic be facing the points or trailing. Some roads also use a bolt lock, operated by the signal, as an additional precaution, even when a switch is locked by a facing point lock. Fig. 3 shows a facing point lock with bolt lock applied to a switch.

### FORM OF SIGNALS

Referring again to Fig. 1, it will be noticed that all signals located on main tracks are shown high and the two located on siding are low, it being the general practice to use high signals for main tracks, in the direction of ordinary traffic, and low or dwarf signals for movements on or out of sidings or against traffic on main tracks. A high signal with square end blade is called a home signal; with the end of blade notched, it is known as a distant signal. A distant blade horizontal means *caution*, that the home signal in advance of it is at danger. When a distant blade is inclined, it means *clear*, and indicates that the home signal is clear also. Therefore, if an engineer approaches a distant signal and finds it at clear, he may proceed at high speed, knowing that the main line route has been set up and ready for him to proceed without a stop; but if he finds the distant at caution, he must approach the home signal expecting to find it at danger.

A dwarf signal with the blade horizontal indicates danger, stop; with the blade inclined, indicates clear, proceed slowly, as move-

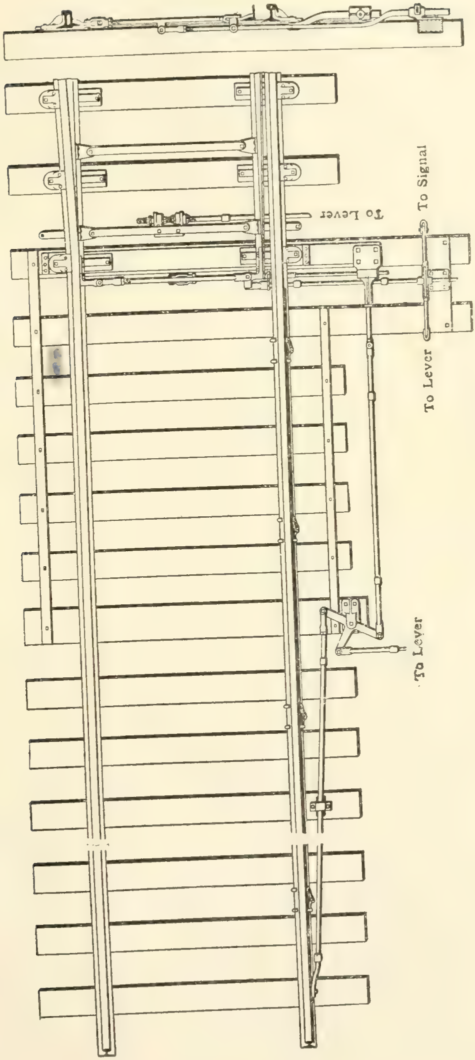



FIG. 3—FACING POINT LOCK WITH BOLT LOCK APPLIED TO SWITCH

ments on or out of a siding or against traffic on main tracks necessarily should be made cautiously.

DETAILS OF CONSTRUCTION

The dotted lines in Fig. 1 leading from the tower along the tracks, indicate the location of the pipe and wire connections from the machine to the various switches, signals, etc., these connections being shown in detail under the heading *Leadout*. In the leadout each full line represents a single line of pipe, and each dotted line represents two wires, each line having a number corresponding to its operating lever. Pipe lines are supported by roller carriers on wood, iron, or concrete foundations, placed every seven feet, and when such lines are over fifty feet long, a compensator (to take care of expansion and contraction due to changes in temperature) is used. Wire lines are supported in the same manner as pipe, except that the carriers are placed every twenty-one feet, and conpensation is usually taken care of by adjusting screws located in the tower.

The letters *ZZ* on the leadout shown in Fig. 1 represent the point on Fig. 4, where the vertical cranks and wheels are located, and through which connection is made to the machine. In the majority of cases machines are located so as to be operated from the second floor of a tower, because it is desirable that a lever man shall have a good view of the tracks and signals. Some machines are built, however, to be operated from the ground floor.

All machines have the levers numbered consecutively, beginning with the left-hand end facing the levers. Mechanical machines may be divided into two classes, thoses having lever locking and those having latch (or preliminary) locking. The levers of all machines are provided with latches, the purpose of which is to keep the levers in the normal or reverse position. In a machine having lever locking, the latch is used for no other purpose than that stated above, the interlocking parts being actuated only by changing the position of the lever itself, which necessarily brings great strain on the locking parts, when an attempt be made to throw a lever when it is locked. Therefore, for such a machine, the locking parts must be made large and strong. In a machine having latch locking, the latch is used not only for holding the lever in the normal or reverse position, but also for actuating the locking parts. That is, these parts are connected to and operated by the latch, instead of the lever, thus permitting lighter construction. As the raising of the latch is a preliminary step to the throwing of a lever, the locking will there-

fore be accomplished before the lever moves from its position. This will be more readily understood by referring to Fig 4, which shows a machine with the levers in the normal position. The machine illustrated is known as the Saxby & Farmer, a type generally used, not only because of the preliminary locking feature, but also because of the design of the locking parts. The parts of

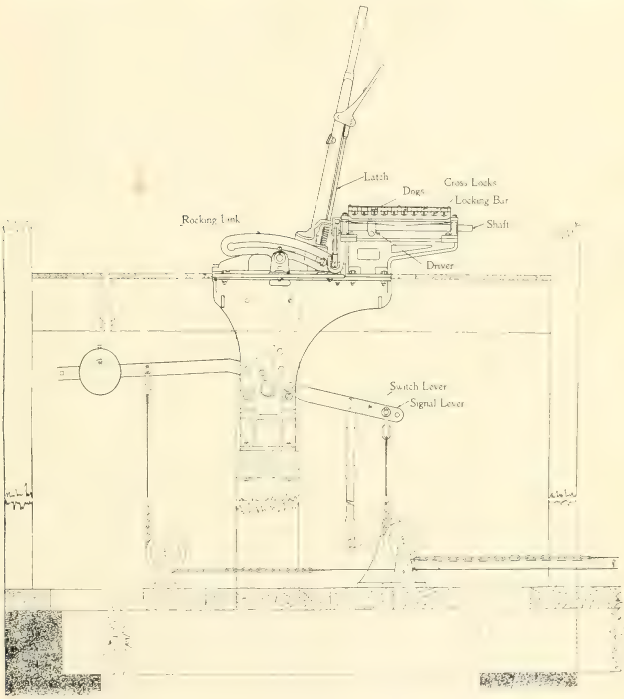


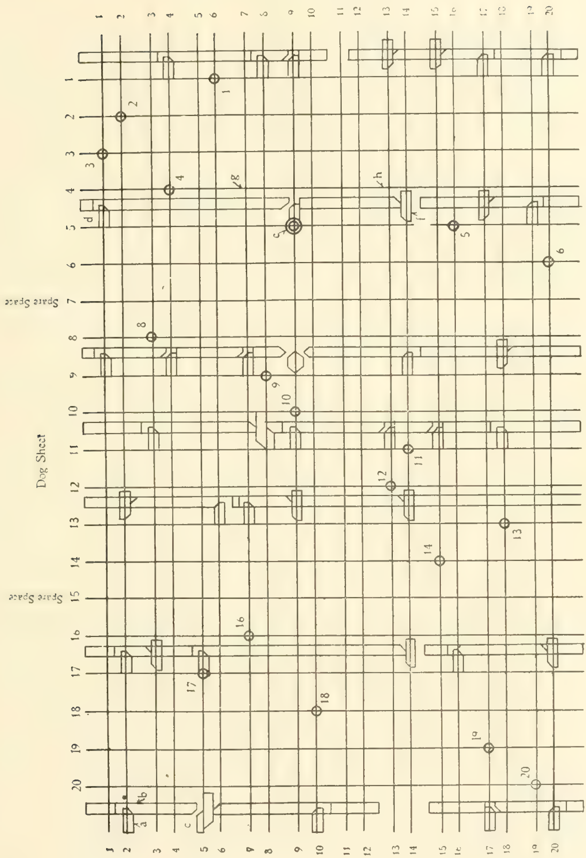

FIG. 4—END VIEW OF SAXBY AND FARMER INTERLOCKING MACHINE WITH CONNECTIONS AS LOCATED IN TOWER

this machine by which the interlocking between levers is accomplished, are known as the latch, rocking link, shaft, driver, bar, dogs, and cross locks. See Fig. 4. When a latch is raised, a bar is moved a certain distance; to this bar dogs are riveted, which in turn drive the cross locks against other dogs which are riveted to bars operated

by other latches. With a lever in its normal position, the raising of the latch gives half of the necessary stroke to the bar, the remainder of which is given by dropping the latch after the lever has been reversed. As the same is true when throwing a lever from the reverse to the normal position, therefore, no matter in which position a lever stands, when the operation of moving it takes place, the first thing to happen is the raising of the latch, which accomplishes all of the locking, then occurs the movement of the lever, during which time no change in the locking takes place, last, the dropping of the latch which releases those levers which are to be thrown next.

Fig. 5 shows a locking and dog sheet, the former showing just what locking is desired, the latter showing the arrangement of the locking in the machine, this diagram being used not only for a record, but also by the shop men, for it is from this that the locking parts are constructed. The numbers at the top of the diagram represent the levers in the machine, and the heavy vertical lines represent shafts operated by the levers. The full length horizontal lines represent bars, each being given a number by which it is known, and each to be operated by some particular lever, by means of a driver which is indicated by a small circle where the lines representing shafts and bars intersect. Hence it will be seen that lever *20* operates bar *19*, lever *9* bar *8*, lever *13* bar *18*, etc. On each bar certain dogs are riveted, which when a bar is moved, drives a cross lock against dogs which are riveted on other bars, thus accomplishing certain locking. To illustrate, notice dog *a* which is riveted to bar *2*, the bar being operated by lever *2*. If the latch of lever *2* be raised, the bar will be moved to the right, thus driving the cross lock *b* against the dog *c*. Hence *2* reversed, locks *17* normal, as required by the locking sheet.

The above is a very simple case, and is called straight locking, being a positive lock between two levers. The following is a more difficult one. For example, a lever to lock another lever depending upon the position of a third. Such an arrangement is shown on the dog sheet by *d-e-f-g-h*. It may be seen that if dog *d* be moved to the right when dog *e* is normal, dog *f* may be moved also, but if dog *e* first be moved to the right, thus filling the space between cross-locks *g* and *h*, then before the dog *d* can be moved, dog *f* must be moved, and when this is done, the moving of dog *d* drives the cross-lock *g* against dog *e*, and as this latter is a swing dog, through it the motion is communicated to the cross-lock *h*, which in turn is driven against dog *f*, and holds it in the reverse position so long as dogs




Locking Sheet

| Lever Reversed | Locks |
|---|---|
| 1 | 2 |
| 2 | 8 11 17 |
| 3 | 4 16 10 10 |
| | 11 w 10 |
| | |
| 4 | 10 |
| 5 | 6 |
| 6 | 12 14 19 |
| 7 | Spare Space |
| 8 | 9 |
| 9 | 10 12 14 |
| 10 | 12 14 |
| 11 | 10 10 13 |
| 12 | 13 |
| 13 | 14 |
| 14 | — |
| 15 | Spare Space |
| 16 | 11 10 |
| 17 | 11 8 |
| 18 | 17 |
| 19 | 14 12 |
| 20 | 19 |

Numbers without circle Lever Normal

Number with circle Lever Reversed

FIG. 5—LOCKING AND DOG SHEETS

*e* and *d* are kept in the same position. Thus *3* reversed locks *11* reversed when *10* is reversed, as required by the locking sheet. This is an example of a very simple case of special locking. In large machines it often happens that the locking between certain levers depends upon the position of perhaps ten or more other levers, and it is this feature which makes the arranging of the locks, as well as determining what locking is necessary, quite an engineering problem. It very seldom happens that any two machines are locked up exactly the same, as the locking required depends entirely upon the number and arrangement of tracks, and the signaling desired.

There are many special appliances and attachments, of both a mechanical and electrical nature, which are often used in connection with an interlocking machine such as has been described, but enough information has been given in this article to enable those who are unfamiliar with interlocking to understand, in a general way, one of the methods used to handle traffic safely and quickly.

# THE CORRESPONDENCE DEPARTMENTS OF THE ELECTRIC COMPANY*

H. D. SHUTE,
Assistant to Second Vice President

AT the first of this series of lectures† first vice president, Mr. Herr, told of the broad scheme upon which the Electric Company's organization is based. It is my intention to tell something of the scope, methods and organization of those East Pittsburg sections which for want of a better name are known as the "Correspondence Departments."

For convenience this general subject will be discussed under the following seven headings:

1—A discussion of the name "Correspondent."

2—General history.

3—Present organization.

4—Duties of the correspondent.

5—Methods of operation.

6—General rules followed.

7—Relations to other departments.

### DISCUSSION OF THE NAME "CORRESPONDENT"

It must be clearly understood at the outset that the name correspondent, as applied in those members of the semi-commercial departments, is an extremely misleading one. An outsider hearing the name immediately thinks of a writer of letters. As a matter of fact, as will be shown later, such letter writing is but a small part of the duties of a correspondent. The name was almost a necessity. Years ago when these departments crystallized, the only word that seemed at all applicable was "correspondent." It has remained in force ever since, although thought has at many times been given with the view of using a better and more explicit title. As a matter of fact, our correspondents are "Jacks of all Trades." With the exception of our management, they are the only employees who have intimate and direct dealings with our legal, sales, credit, auditing, purchasing, engineering and works departments.

### GENERAL HISTORY

The present organization of the correspondence departments has

* A lecture delivered before the Electric Club on November 26, 1906.
†See THE ELECTRIC JOURNAL, Vol. III, p. 682, December, 1906.

been the result of growth and experience during a period of over fifteen years. While the business of the Company was comparatively small, there were few, if any, district offices, and the work now done by the correspondents was handled by the salesmen, engineers, or heads of the commercial departments, who were then all found at the main offices on Garrison alley in Pittsburg. As the business grew, it became necessary for the commercial managers to delegate the handling of contracts, orders, shipments, etc., to other men. When I entered the employ of the company in 1893, the main part of the present duties of the correspondents was being handled by Mr. D. C. Arlington and Mr. J. M. Duncan. Since then the business has greatly increased until at the present time there is being handled thirty times the business of thirteen years ago. The number of quotations to be made, contracts, orders and letters to be handled, has increased in even greater proportion than has the volume of business. The amount of so-called correspondence work is now forty times what it was just previous to moving the work to East Pittsburg in 1894. As the business increased, new methods of handling it naturally developed. The work now done in the correspondence departments was at one time divided between two sets of men. The first set made the quotations, promises of shipment, and straightened out the tangles in contracts and orders. After the orders were in commercial shape, they were referred to the second body of men who wrote the general orders, conferred with the engineers, and saw that the apparatus was properly built and shipped.

During 1897 these two sets of men were combined. The work was then sub-divided, the approximate divisions being:

Railway apparatus,

Direct-current, light and power apparatus,

Polyphase apparatus,

Single-phase apparatus,

Detail apparatus.

In 1898 these divisions were somewhat simplified. Mr. E. W. T. Gray was placed in charge of the railway and direct-current light and power sections. Mr. Dusinberre took charge of the alternating-current apparatus and Mr. Ruggles was manager of the detail section. These divisions became known as the D. C., the A. C. and the Detail departments. There was in addition a foreign correspondence department under Mr. H. M. Wilson. Later on the foreign section was absorbed by the main departments and still later on a Canadian correspondence department was formed with Mr. H. M. Bostwick in charge.

The three main divisions just mentioned continued under changing chiefs until last year. The D. C. department was successively in charge of Messrs. Gray, Ebert, Duncan and Rohrer; the A. C. department in charge of Messrs. Dusinberre, Shute, Kollock and Cope; the detail department under Messrs. Ruggles, Reed, Goodby and Mackie.

PRESENT ORGANIZATION

On November 1 of last year the present plan of organization went into effect. Up to that time the division of work had been along arbitrary lines which were not in accord with the segregation of the engineering, sales or works departments. The new scheme was intended to bring the correspondence sections more nearly in line with the

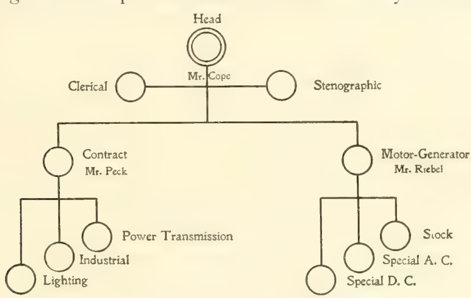



FIG. 1—POWER DIVISION OF THE CORRESPONDENCE DEPARTMENT

sales and engineering sub-divisions. The new and present organization consists of three main sections:

The power department,

The railway department,

The detail and supply department.

These will be briefly explained by diagrams.

Fig. 1 shows the organization of the power department, under the leadership of Mr. H. W. Cope. This department handles the work incident to contracts and orders for power, industrial and lighting apparatus, and including all such apparatus, exclusive only of the detail and supply material. The diagram in Fig. 1 is self-explanatory. At the present time the working force consists of fifty-three correspondents, clerks, stenographers and office boys.

Fig. 2 represents the scheme of organization in the railway department. The chief of this department is Mr. F. F. Rohrer. All work incident to orders for railway apparatus, with the exception

of details, is handled here. In addition, all orders for foreign shipment, with the exception of details, are attended to in this department. The working force consists of twenty-nine correspondents, stenographers, clerks and office boys.

The scheme or organization of the detail and supply correspond-

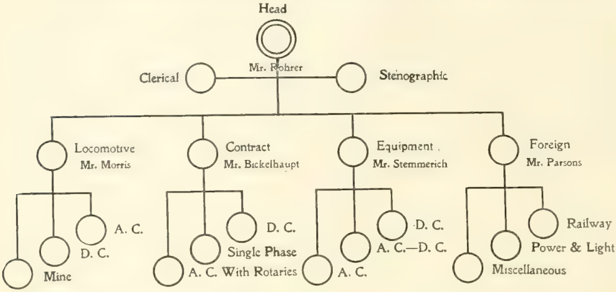



FIG. 2—RAILWAY DIVISION OF THE CORRESPONDENCE DEPARTMENT

ence department is shown in Fig. 3. This department is in charge of Mr. Mackie. Here are handled all contracts and orders coming under the classification of detail and supply business. This department also includes a section which looks after repair orders. At the present

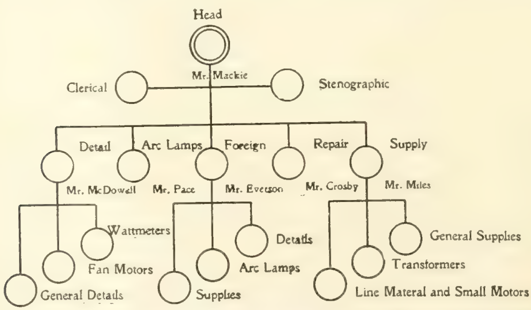



FIG. 3—DETAIL AND SUPPLY DIVISION OF THE CORRESPONDENCE DEPARTMENT

time the working force consists of thirty-seven correspondents, stenographers, clerks and office boys.

From these diagrams it may be seen that the division of work has been drawn sharply. There is no reason why any district office salesman should not know at once to which correspondence department to address a letter on any particular subject.

### DUTIES OF THE CORRESPONDENT

The principal duties of the correspondent may be enumerated as follows:

1—To answer inquiries from district offices regarding (a) technical information, (b) prices, (c) shipments, (d) miscellaneous.

2—To examine and pass upon incoming orders and contracts.

3.—To enter all general orders and carry on correspondence regarding same.

4.—To assist the production department in lining up the work in the various shop sections.

5.—To keep up the stocks of standard apparatus.

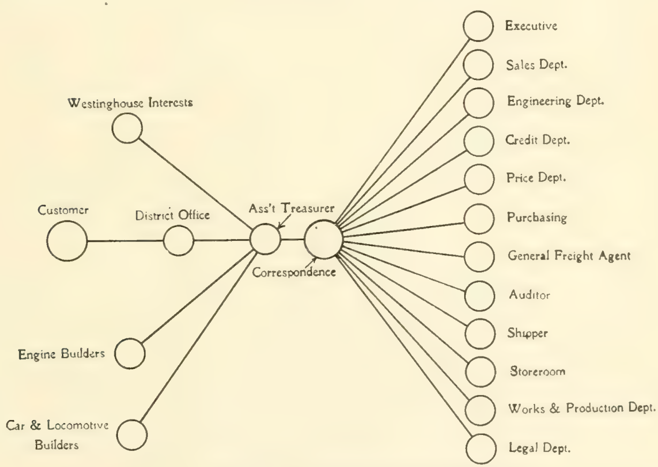



FIG. 4—METHOD OF HANDLING CORRESPONDENCE

In addition to these main duties, there are countless other duties of a more or less tangible nature.

### METHODS OF OPERATION

By means of the diagrams in Figs. 4, 5, 6 and 7, the general methods followed in handling letters, telegrams and orders may be seen.

Fig. 4 is intended to represent in a very general way the method of handling the large bulk of our correspondence. Practically all of our correspondence originates with prospective buyers. These buyers

make inquiries of our district offices, who in turn write to East Pittsburg for data and advices. All mail coming to East Pittsburg goes at once to the assistant treasurer's office, where letters are opened, checks and currency in payment of bills carefully appropriated, the mail sorted and promptly delivered. Certain letters are for the executive officers, sales managers, auditor, purchasing agent, treasurer, credit manager, etc., but a very large proportion are addressed to one or the other of the correspondence departments. Most of the mail reaches the offices at 8:30 A. M. For the first half hour the entire force of the assistant treasurer's office is busy opening and sorting mail. At 9:00 A. M. the correspondence departments' mail has been delivered and in turn distributed to the proper individual correspondents.

When the correspondent receives a letter making request for data, he consults with one or more of the departments shown in Fig. 4,

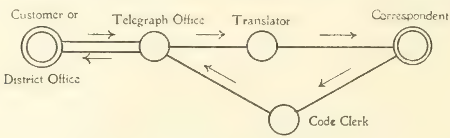



FIG. 5—METHOD OF HANDLING TELEGRAMS

obtains the precise information wanted and then writes to the proper district office. Upon receipt of the correspondent's letter, the district sales office in turn advises their customer. This method of procedure is based upon the firmly established rule that all communication with customers and prospective buyers shall be made through the nearest district office. From the diagram it may be seen that there are certain exceptions to this rule, the most important of which are indicated on the diagram.

The number of letters received by the various correspondence departments every week is approximately as shown in this table:

| | |
|---|---|
| Power department | 2 500 |
| Railway department | 700 |
| Detail and supply department | 1 700 |
| Total | 4 900 |

Fig. 5 represents the method of handling Western Union and Postal telegrams. Such messages in general come to us and go out from East Pittsburg in code. In addition to such messages an enor-

mous telegraphic correspondence is carried on over our private line, connecting the main offices with New York and Newark. The following table, showing the record for a week in November, will be of interest:

| Telegrams. | Sent. | Received. |
|---|---|---|
| Private wire | 636 | 702 |
| Western Union | 386 | 433 |
| Postal Telegraph | 427 | 381 |
| Ocean cable | 15 | 14 |
| | 1464 | 1530 |

Fig. 6 represents very crudely our system of handling contracts. When a prospective buyer has closed with a salesman for certain machinery, the proposal prepared in the district office is signed in duplicate by the customer and both copies forwarded to the district

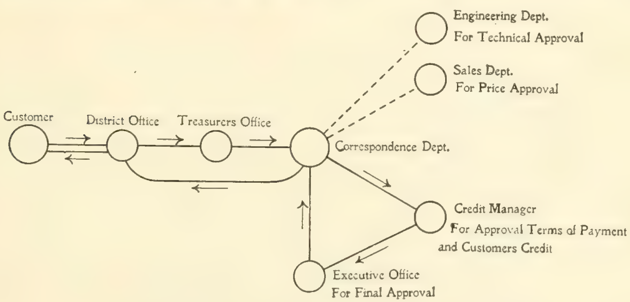



FIG. 6—METHOD OF HANDLING CONTRACTS AND ORDERS

office. At the district office the contract is carefully checked and the necessary form sheets attached thereto. The two copies of the contract, with form sheets and explanatory letter, are then mailed to the respondents at East Pittsburg. In regular course these papers are received at the assistant treasurer's office, one copy of the form sheet, giving financial information, is handed to the credit manager, and the contract, letter and other form sheets sent to the proper correspondence department. The correspondent then obtains sales manager's approval of price and engineering department's approval of any unusual technical features. These approvals having been settled, the two copies of the contract are sent to the credit manager for credit approval and thence to acting vice president McFarland, for final and executive signature. They are then forwarded to the correspondent, who files one copy of the executed

contract in the vault and sends the other copy to the customer through the district office.

The method of handling minor orders, which are not on contract forms is similar to that indicated above, except that formal signature by an executive officer is not obtained.

The number of orders now being handled by us per month is indicated in the following table:

| | |
|---|---|
| Power department | 1 500 |
| Railway department | 150 |
| Canadian department | 250 |
| Detail and Supply department | 4 000 |
| Total | 5 900 |

Fig. 7 shows the method of handling general orders. Contracts,

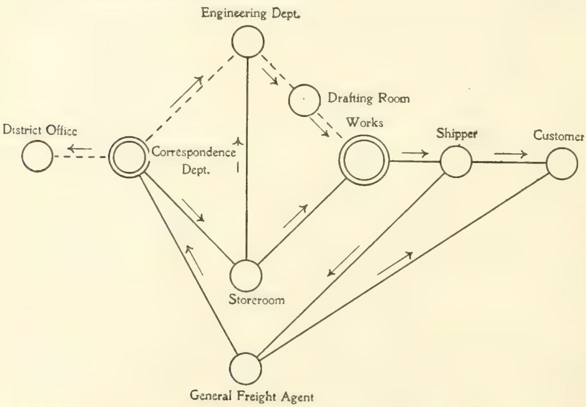



FIG. 7—METHOD OF HANDLING GENERAL ORDERS

original customers' orders and district office requisitions do not go directly to the engineering or works departments. A general order is a schedule prepared by the correspondents and represents the correspondents' interpretation of the contract or order. Such a general order contains instructions to the storekeeper, works, auditor and shipper and constitutes the instructions from our commercial departments to our East Pittsburg departments. The progress of the general order is shown on the diagram. After being prepared in the correspondence department, one copy of the general order is sent to the district office, one copy retained by the correspondent, and the original and other copies are sent to the storekeeper. The items cov-

ering standard and stock apparatus are taken care of by the storekeeper. For special items, shop orders are entered by the storekeeper and forwarded to the engineering and works departments. The engineers, upon receipt of the shop orders, prepare designs and material specifications which, together with the necessary drawings, are sent to the works. The necessary information in hand, the works make the apparatus and turn it over to the storekeeper. When all the special standard and stock apparatus is ready, the shipper boxes the material and makes shipment in line with the instructions on the general order. Shipping lists are prepared by the shipper and forwarded to the general freight agent in order that the customer, district office and correspondents may be promptly notified by him of the shipment and the contents thereof.

### GENERAL RULES FOLLOWED.

There are at present in force 1 106 general letters issued by our executives. Of these about one-third contain some rule for the guidance of our correspondents. Only a few of these many rules will be discussed.

One of the rules governing the commercial correspondence is to the effect that the customers shall not have direct dealings with the the works. Naturally many customers would like to get in direct communication with the East Pittsburg correspondents and engineers. Such practice, if allowed, would tend to discredit the district offices and the continued practice would place the customer out of touch with the salesmen. The salesmen and customers should be in the closest possible contact, and right here the necessity of cooperation of departments is shown. To illustrate, assume that a customer writes direct to the works for some engineering data. The letter is received by the correspondent. The wrong way to handle the case is for the correspondent to reply direct and fully to the customer. The effect of such action upon the customer's mind is readily imagined. He feels that good and effective service can be obtained by going direct to headquarters and he rather likes the idea of hearing first hand from East Pittsburg. He determines that in future he will not bother the district sales office. When it comes time for him to purchase new apparatus, he will get on a train bound for Pittsburg with the idea still in his head that he will fare better by so doing than he would by calling in one of the salesmen. But that is just what is not wanted. The works office force is all too busy to be overrun by customers, and besides there is an established sales policy to the

effect that all dealings with customers are to be done through the district office force.

The right way to handle the case just cited is as follows: Upon receipt of the customer's letter, the correspondent should promptly reply, telling the customer that his letter has been referred to such and such district office from whom he may expect early and complete reply. This is team work. It puts the district office in good standing and enables the salesman to get in touch with a prospective customer. At the same time the customer has learned that service is only to be obtained through the district office. The chances are that after such an occurrence the customer will in future look to the salesmen for all data regarding our apparatus.

This rule having for its object the doing away with district correspondence between customers and works has, of course, exceptions. Take for example an irate customer who feels, for one reason or another, that he has been misused and complains thereof to headquarters. It would be adding insult to possible injury to tell him ever so politely to communicate his troubles to the nearest district office. The following letter, which came to me last Saturday, is a case in point:

November 21, 1906.

Westinghouse Electric & Mfg. Co.,

*Gentlemen:*

Your telegram and letter of 14th inst. stated that pulleys for generator and exciter for 50 K.W. plant recently purchased would be *positively* shipped on 19th inst. On 20th we received pulley for exciter. We thought Adams Express were in fault, but were assured by manifest that only one pulley was shipped. We want the missing pulley.

We are losing money by the wretched delay made for us. We are more than disgusted—we are provoked.

Give us an order or allow us to get proper generator pulley, your account, and we will show you Pittsburg elephantine slowness will be eclipsed by Baltimore enterprise and promptness.

Say and say quickly what you will do.

Respectfully,

.......................

The generator pulley had already been shipped and the proper answer thereto was a prompt telegram sent direct to the customer reading as follows:

"Letter received. Regret your annoyance. The missing pulley was shipped you from Baltimore yesterday by express."

Another rule of the company in connection with outgoing letters is that they be brief. With the use of phonographs there is a marked tendency towards wordiness and this too often means that facts conveyed are not set forth distinctly. The primary idea of a letter is con-

versation at a distance. If this be kept in mind, one can scarcely fail to write appropriately, if one can talk to the point. In answering a letter of inquiry from a district office, it is a good plan to note the different items of information requested and then make sure that the answering letter briefly, definitely and consecutively makes reply thereto.

It is the established practice of the Electric Company to omit any formal opening or closing of letters not only between departments, but also in corresponding with the subsidiary companies. The aim is to avoid wherever possible all unnecessary typewriting. Careful letters are desired, all frills should be omitted.

### RELATIONS TO OTHER DEPARTMENTS.

Speaking on this subject, Mr. Goodby once remarked, "When an irresistable force meets an immovable body, then results the correspondence department." The correspondent stands as a buffer between the district offices on the one hand and the engineering and works departments on the other. Through these correspondence departments, East Pittsburg comes officially in touch with the commercial world. As before stated the correspondents come in active touch with all of the other departments of the company. They are the clearing house. They furnish the salesmen with information of all kinds pertaining to the business and transmit to the manufacturing sections the orders secured by the salesmen.

The correspondence departments have mostly to do with the sales, engineering and production departments. This can best be illustrated by an example. Assume that the Illinois Steel Company is in the market for a 1 000 kw alternator. A Chicago office salesman sees the customer and finds that an engine type machine is wanted, of certain characteristics. His price lists do not show such a machine listed. The Chicago office writes to the power department at East Pittsburg, mentions the negotiation and asks for prices, performance specifications and shipment of the generator in question. Upon receipt of this letter the proper correspondent at once confers with the price department, the engineering department and the production department. From the price department a statement is received of the cost and selling price of the machine. The engineering department furnishes performance specifications, weight and outline dimensions. From the production department is received an estimate of the length of time normally needed to build the machine. With this data in hand the correspondent consults one of the

sales managers in order that any special directions may be followed. This done a letter is written to Chicago giving the full data required and adding thereto any information which may aid the salesman. As the deal progresses it may appear that modifications in the specifications or shipment of the machine are necessary. In such case the Chicago office puts the facts before the correspondent, who, in turn, again confers with the engineers, production department, sales managers or executive, and advises the Chicago office of the further position that the company may desire to take.

This example shows only one phase of a correspondent's duties, but it illustrates the necessary close interrelation existing between the correspondents and the other main branches of this somewhat complex organization. For the attainment of a correspondent's maximum efficiency, it is necessary that he be thoroughly in touch with the departments from which he obtains and to which he sends information. He must be in sympathy with the salesman in the field and must have an intimate knowledge of shop conditions, of the rules governing credits, of engineering facts and details, and of the underlying general policies governing the conduct of the business. Team work is necessary and the correspondent is the quarterback who is giving the signals. If the correspondent gets the idea that his duty is simply to act as a transmission clerk, he will not make a success. The men who realize what the position means, who use their brains and try to promote the sale of the company's product by doing all in their power to help the salesmen, are sure of almost immediate notice and promotion.

The position of any of the principal correspondents is such that the harm or good that they can do towards increasing the company's business is incalculable. And this harm or good depends entirely upon the spirit in which the correspondent takes hold of his duties. Above all, co-operation with the other departments is necessary. The position of correspondent is one requiring executive ability—and in truth the correspondents to a large degree are the medium through which the officers' plans and policies are expressed. Even the entering of a general order requires executive ability. All the loose ends of a contract must be bound together and the customer's wishes, as therein set forth, carried out to a prompt and successful conclusion.

The correspondence departments offer a very fine training in commercial lines. This has been demonstrated time and again by the graduates from these departments. A few only may be mentioned of the many who fully realize that their present commercial success

is to no slight extent attributable to the training received by them while in correspondence work.

E. N. Sanderson, of Sanderson & Porter.

Calvert Townley, vice president of the Consolidated Railway Company.

A. S. Morris, of the firm of P. H. and A. S. Morris.

E. W. T. Gray, until recently manager of the New York office of the Electric Company.

Henry C. Ebert, president of the Cincinnati Car Company.

R. L. Warner, until recently New England general agent of the Electric Company.

These men grasped the idea that co-operation and team work were necessary and went out of the routine way to aid the departments at their right and left hands.

The correspondent must not stand aloof. He cannot sit calmly at his desk day after day perfunctorily carrying out routine duties only. He must overlap into the other departments, must have the details of his particular line of work at his finger tips, and must above all in his difficult position always maintain pleasant and courteous relations with his co-workers in other departments.

# NIAGARA POWER AT THE LACKAWANNA STEEL PLANT

JOHN C. PARKER
Mechanical and Electrical Engineer

A FEW years ago the West Seneca works of the Lackawanna Steel Company were established. At these works electrical energy is used for many of the incidental processes. Owing to the large size of the gas engines, and the extent of the installation considerable attention was attracted to the equipment for utilizing blast furnace gases for the generation of power. This gas engine plant was installed for the purpose of operating motors at various points in the plant, these being used for large cranes, gantries, unloaders, conveyors, etc., for the operation of a trolley system, and

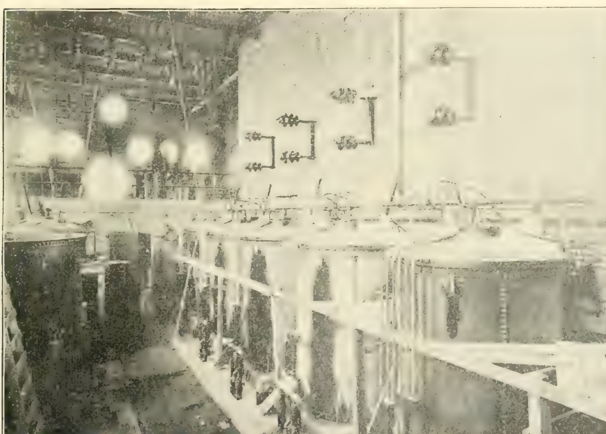
VIEW OF TRANSFORMER SUBSTATION AT THE LACKAWANNA STEEL COMPANY'S PLANT
Messrs. Green and Wicks, Buffalo, N. Y., Architects.

for the operation of roll tables in the mills. The load is of a decidedly fluctuating character on account of the frequent starts and stops, and the concentrated character of the loading. The load factor, however, is very good as compared with that of a railway or lighting plant.

The utilization of the blast furnace gases necessitated the concentration of the power generating equipment in one point, so that, with the extension of the plant, considerable losses have become inevitable in transmitting the power at the present low voltages of 250 volts direct current and 440 volts alternating current. To adopt a distributed generating system would involve the abandonment of the

gas engine as a prime mover. On the other hand, if the concentrated system were to be retained, extensive and more or less unsatisfactory step-up apparatus would be necessary to cut down the losses in the alternating current network, entailing a remodeling of the cable system to accommodate the higher voltage. Nothing whatever could be done to remedy the extensive loss in the direct-current distribution, unless inverted rotary converters were made use of at the power house and corresponding converters at the point of utilization, an arrangement which possesses manifest disadvantages and would be tremendously costly.

As the steel works have grown, the demand for power has ex-



INTERIOR OF TRANSFORMER SUBSTATION AT THE LACKAWANNA STEEL COMPANY'S PLANT
Messrs. Green and Wicks, Buffalo, N. Y., Architects.

ceeded the present supply of blast furnace gas, so that extension of the local generator plant would have involved the use of coal, which would have been out of the question as a competitor to Niagara Falls power. Some advantage obtains from the fact that the capacity of the Ontario Power Company's generating plant is very large in comparison with the normal demands of any individual customer. This gives assurance against interruption due to disabled generating apparatus and permits the occasional carrying of a great excess over the ordinary loads. An appreciation of these facts has led the

Lackawanna Steel Company to contract with the Niagara, Lockport & Ontario Power Company for electrical power, transmitted from the plant of the Ontario Power Company at Niagara Falls, Ontario.

The brief description here given of the installation for transforming and distributing this power in the works of the Lackawanna Steel Company, together with a discussion of the more salient features, it is hoped, may prove of some interest. In any event, the rapid progress of the electrical art makes desirable a frequent comparison of notes regarding methods of design and operation.

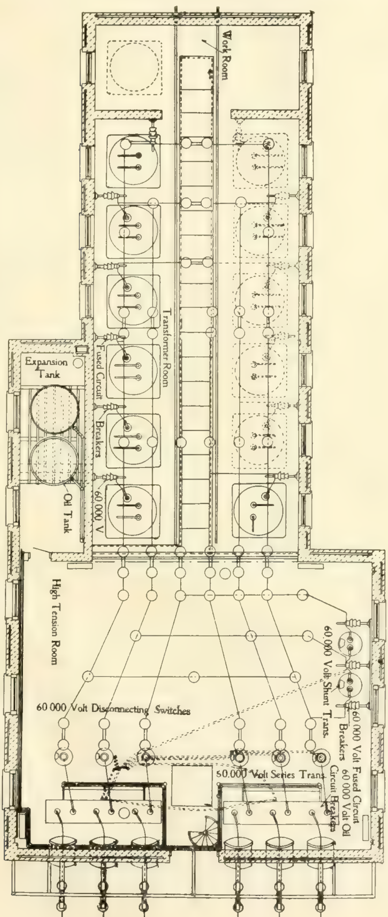
The engineers of this work had primarily in mind three features, very usual ones in any engineering installation, namely, reliability and continuity of service; facility of operation and, maximum total economy. The paramount importance of reliability in such an enterprise as that of the Lackawanna Steel Company is so obvious as to require no comment. It was felt that reliability could be best attained by the utilization of as absolutely simple and "fool proof" apparatus as could be obtained, and by making all parts of the construction straight-forward, simple and readily accessible at all times. This condition in the design accomplished the other two ends which were desired.

The new electrical equipment, in general, consists of four stations; the substation containing transformers which step the energy from 60 000 volts to 2 200 volts; and three feeder stations, which receive the energy at 2 200 volts at as many different points in the plant and there convert it to 440 volts alternating current and 250 volts direct current. It is with the equipment of these stations and the intermediate 2 200 volt feeders that the present article is concerned. The 60 000 volt transmission line supplying the plant is a part of the system of the Niagara, Lockport & Ontario Power Company, designed under the engineering direction of Mr. R. D. Mershon.

### 60 000 VOLT SUBSTATION

*Incoming Lines*—Power enters the substation at 60 000 volts through disconnecting switches which may be operated from a balcony on the front of the station building; thence passing inward through oil circuit breakers and series transformers, it is delivered to the station bus-bars which form a loop immediately under the ceiling. These bus-bars are of one-fourth inch copper tubing, supported by standard 60 000 volt line insulators. In the oil switch room a cross-connection is provided so that power may be delivered

to either side of the loop from either incoming line. The high voltage bus-bars are sectionalized by inverted knife switches hung from to either side of the loop from either incoming line. The high voltage bus-bars are sectionalized by inverted knife switches hung from the roof, so that each bank of three transformers may be isolated for changes in the bus-bar system, or for cleaning insulators, if desired.




PLAN VIEW OF TRANSFORMER AND HIGH TENSION ROOMS OF SUBSTATION

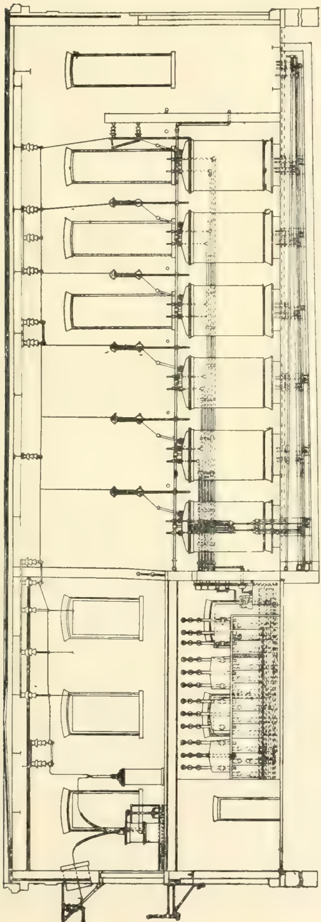
*The Transformers* — From the 60 000 volt bus-bars current passes through fused circuit breakers — which act as an auxiliary and selective protection to the various transformer banks, and thence in at the top of the transformers. The transformers are arranged in two rows of six each, and are of 1 000 kw capacity at normal loads and are of the oil-insulated, water-cooled type. Of the ultimate twelve transformers, six only have been installed at present, making two banks with a seventh or spare transformer with means for connecting it into the place of any of the six. The secondaries

are wound for 2 500 volts with intermediate taps down to 2 200 volts, and are delta-connected, the primaries being star-connected, and having the neutral formed by internally grounding one end of each winding to the transformer case, which is in metallic contact with a pair of rails embedded in the building foundations, as well as with the water and oil pipe systems. The transformers rest on I-beams bolted to these rails, and can, by the insertion of steel rollers, be skidded off the I-beams to a small transfer car which runs on tracks in the middle of the transformer room. Two spare transformer stands are provided in a room at the rear end of the station, in which transformer cases may be assembled, oil dried and tests run. This room is served by a fifteen ton chainblock hoist supported by a twenty-four inch transverse I-beam immediately under the roof. This arrangement obviates the need for a crane in the building with its attendant objectionable features. The transfer truck may be run out on rails at the rear end of the building and the transformer lifted by means of a railroad yard crane onto the tracks of the plant, so that any part of the transformer may be carried to the machine shop, or elsewhere for repairs.

*Transformer Compartments*—Careful investigation has proved that it would be practicable to install the transformers without isolating barriers; in fact, that such provisions are not only unnecessary but are positively objectionable because they involve complications in construction and prevent the greatest accessibility. Accordingly the transformers have been placed with no barriers, and with only sufficient space between them to allow proper electrical clearances and safe accessibility for inspection.

*Transformer Oil Systems*—A similar investigation has led to the abandonment of the more complicated fire quenching and oil emptying systems which have been quite commonly employed of late. The recorded facts in regard to transformer difficulties seem to bear out the theory that these transformers are about as good a fire risk as can be had when placed in a building of fire resisting construction and containing no large quantity of combustibles. The small quantity of air in the transformer cases and the difficulty of igniting insulating oil renders impossible the development of any high pressures, and improbable the ignition of oil vapors. Of course a protracted short-circuit occurring simultaneously with non-operation of the fused circuit breakers and of the oil circuit breakers, would result in the building up of internal pressure, due to the boiling of the oil, a condition which is very remotely extreme. To

guard against any possible difficulty from such excessive internal pressure, the transformer cases have been vented at the top to two and one-half inch pipes leading both to the roof and to the sewer system, and each vent is provided with a check valve for the exclusion of moisture, as well as for the prevention of the communication of difficulties from transformer to transformer. This system gives all desirable safety and prevents the liability to accident due to the excessively complicated systems of piping involved in sewer drains and flushing connections.



SECTIONAL ELEVATION OF SUBSTATION

In recognition of the desirability of being able to periodically cleanse and dry the oil used in the transformers and, at the same time, to empty and re-fill transformer cases rapidly in the event of accident, a system has been adopted which combines gravity emptying and gravity filling with a filtration and drying of the oil in pasage from the submerged storage tank for impure oil to the elevated storage tank for clean oil. Entirely separate lines of piping are carried through a central trench in the building for the purpose of carrying oil to, and away from, the transformers so as to prevent

the trapping of impure oil which would be washed back by the clean oil in re-filling if a single line was used. The filling and emptying pipes are two and one-half inches in diameter, and of short run so that the gravity head can fill a transformer tank in a very short time, much shorter than could be attained with any reasonably small pump, acting directly.

*2 500 Volt Wiring and Bus-bars*—Current passes through cambric-insulated cables from the transformer secondaries along the transformer room walls into the switchboard room, and through oil circuit-breakers, to the station bus-bars. The station bus-bars are at present a simple straight run of one-eighth by three inch copper straps supported on 5 000 volt line insulators by studs fastened into the wall. It is expected that the excellence of the insulation will obviate the necessity of a parallel bus, but provision is being made at the present time for extending the present bus all the way round the switchboard room to form a ring, divided into sections by knife switches; thus segregating the various feeders and transformer taps. The present four feeders supplying the Steel company's plant will be taken out through oil circuit-breakers to 500 000 c.m. three-phase, 2 500 volt cables and thence through an underground conduit system to the various feeder stations.

## THE DISTRIBUTING SYSTEM

All secondary current at present delivered to the Steel Company's plant from the sub-station will be transmitted to feeder station No. 2, although it is believed that ultimately feeders will be segregated and run to the various centers of activity, their outer ends being connected to form a ring system for the improvement of the load factor on the feeders. Perhaps no part of the installation has been a matter of so careful and anxious thought as this distribution system. The conditions of mechanical operation in the plant are so extremely severe as to render it impossible to do anything in the way of cutting fine the design of the duct system. After numerous studies had been made the engineers of both companies finally settled upon the standard construction of the Lackawanna Steel company which consists of a group of quadruplex tile duct, carried on pile foundations by reinforced concrete arches of thirty foot span. The arches are necessitated by the extremely light character of the soil found in most parts of the company's grounds which requires extensive piling for almost all structures placed. Any of the more ordinary types of duct construction was prohibited

by the liability to fracture, due to the inevitable and indiscriminate placing of heavy stacks of billets, rails, etc., and the running of the railroad tracks through all parts of the plant.

The cable sections have been calculated to meet three conditions; first, when all are in commission and carrying normal load the cables should develop the minimum annual cost for power distribution; second, when one-half of the cables are out of commission for repair, or change, or on account of accident, the voltage drop must not be too large for the operation of synchronous apparatus, or for regulation; third, under these conditions of double normal overload on each cable, overheating of the cables shall not result. These of course are the conditions ordinarily obtaining in such work. As the distance of the transmission is short and the secondary voltage reasonably high, meeting the first condition has fulfilled the other two.

The secondary voltage for the plant was determined by a comparison of the economies resulting from the voltage selected and double this voltage. The annual cost of distribution is so low with the conditions chosen that the superior economy resulting from the higher voltage is very small, and although switching apparatus could be a little lighter with higher potentials, operative safety is felt to be sufficiently greater with the voltage chosen to warrant even a considerable sacrifice for the sake of insuring continuity in operation and safety to the operatives.

### THE FEEDER STATIONS

A detailed description of the feeder stations is scarcely warranted as they involve nothing unusual. No. 1 feeder station consists of an installation of one bank of 2 200 to 440 volt, 375 k.v.a. oil-insulated, self-cooled transformers connected in double delta together with two 1 000 kw and one 500 kw synchronous motor-generator sets for conversion from 2 200 volts alternating current to 250 volts direct current. These machines are all installed in the power house of the Lackawanna Steel company, and feed into the present extensive switchboard. This station is fed from feeder station No. 2 by means of three-phase cables, No. 4/0 per conductor.

Feeder station No. 2 receives all the energy delivered from the sub-station and distributes it by means of non-automatic oil switches to feeder stations Nos. 1 and 3. It has an equipment consisting of a bank of double delta 2 200 to 440 volt oil-insulated, self-cooled, transformers, and two 500 kw synchronous motor-generator sets. Provision is made for a second bank of transformers. The equip-

ment at feeder station No. 3, which is connected to station No. 2 by means of duplicate overhead feeders, is similar to that of No. 2 feeder station, except that there is only one motor-generator set, and that the present transformer bank consists of 100 k.v.a. transforers.

OPERATION

*Method of Improving the Power-Factor*—The present direct-current load at the steel plant is much in excess of the alternating-current load and the plant load factor is very good. The alternating-current power-factor, however, is not very high as the equipment consists of relatively small induction motors, many of them running at only fractional loads most of the time and starting frequently. As the purchaser of power wishes to keep it up to as nearly unity power-factor as possible, both for economy in his own conductors and in view of the conditions of purchase, some form of synchronous apparatus was desired to compensate for the lagging alternating-current load. Three methods were suggested: first, the installation of a synchronous condenser; second, the use of rotary converters; third, the use of synchronous motor-generator sets.

Had the first scheme been adopted it would have necessitated the building of a machine with very special characteristics, and the installation of a special switchboard to take care of it, the use of valuable room, and moreover, the very large and unnecessary expense of building a machine specifically for this purpose, whereas by combining load current with wattless leading current in already loaded motors, the same result can be very economically obtained Moreover, the correction for lagging current would have been felt only at the point where the synchronous converter was placed, and not on other parts of the distribution system so that only one of the objects would have been fully accomplished. On the other hand, this offers the advantage that the sub-station operator has the control of power-factor in his hands rather than having it distributed in the various feeder stations.

Either rotary converters or synchronous motor-generator sets would have attained the end sought for, and it became a question between these two. There is hardly any difference in cost or efficiency between the motor-generator sets taking current directly at 2 200 volts and rotary converters with their accompanying transformers. As the 250-volt distributing system of the Lackawanna Steel Company offers a common connection between all the generators in these sets it was desirable to find some means of apportioning

the load between various stations so as to keep as high an equipment load factor on the converting apparatus as possible. This could be done by varying the field excitation of converters if sufficient line reactance were present or were introduced, but such an end would be attained only at the sacrifice of phase control. Moreover, it was desired that this end should be accomplished more or less automatically by having the voltage characteristics of the generators rise from 250 to 275 volts at full-load, and then to sharply drop so that the machine would automatically "lie down" on overloads, an end impossible in a well designed rotary converter.

*Equalizing the Load*—As it is desired that the draft of power from the Ontario Power company's generating plant shall be free from peaks, the Lackawanna Steel company will operate part of its present equipment in parallel with the transmission line. For this reason, as well as for the equalization of loads on the various machines, it was desired that the voltage of the converting apparatus should be above the voltage of the original plant of the Lackawanna Steel company up to a point representing normal load on the former machines, and that the voltage should then drop to a value below that of the old plant, that is, the regulation of the new installation should be purposely made rather poor above a certain value of load. Below this point the Niagara transmission will tend to take all of the load, but no additional load above this point.

If rotaries were used giving a continuous drop of voltage from no-load, the voltage characteristic of the new plant could be made to intersect the more nearly flat voltage characteristic of the present equipment, but such an intersection would be "long" and liable to large displacement due to the variations in the voltage of the transmission line, or of the machines which might be run for the purpose of flattening the peaks. Moreover such an arrangement would not tend to prevent excessive overload of the individual converters in the immediate vicinity of a concentrated load and would give obviously bad voltage characteristics on the system as a whole. These considerations led to the selection of the present synchronous motor equipment.

This article can scarcely be regarded as complete without an acknowledgment of the kindly and generous assistance received from the engineers of the Westinghouse Electric & Manufacturing Company, who supplied the electrical equipment, and of the ample support given by the officials of the Lackawanna Steel Company,—

especially should be mentioned Mr. W. A. James, chief engineer of the Lackawanna Steel Company, and Mr. G. M. Sturgass, electrical superintendent. The pleasure of association with these gentlemen has added much to the interest of the development. The architectural treatment of the sub-station was in the hands of Messrs. Green and Wicks, of Buffalo, who have given an unusually satisfactory appearance to the building. It has been particularly gratifying to note how very good an appearance has been obtained by keeping the design strictly consistent with the purpose to be attained, that is, by a strong and simple treatment of the structural material with absolute freedom from attempts at ornamentation.

Good form restricts the writer from making as complete an acknowledgment as he would like, of the direction and guidance received from his chief, Mr. F. B. H. Paine, under whom, as chief engineer of the Iroquois Construction company, this work was carried out.

# THE WIRING OF SMALL CENTRAL STATIONS

## THE WORK AND RESPONSIBILITY OF THE ERECTING ENGINEER

S. L. SINCLAIR

THE installing of cables, small wiring and accessories in central stations and isolated plants of small and medium size, is too frequently given secondary consideration. The operation of any electric plant unquestionably depends largely upon this factor and it is remarkable how some plants are operated for long periods under most adverse conditions, in so far as the wiring is concerned. The successful operation of a plant frequently depends upon the ability of the erecting engineer to decide as to the details of wiring, as little or no consideration may have been given to such matters previous to the arrival of the generators and other machinery, especially if the contract includes his supervision of all construction. It is therefore necessary for the erecting engineer to be prepared to decide and answer questions upon this subject which will include the size of cable required for main and field leads and methods of supporting them; the location of switchboard, means of supporting it, and the best method of wiring from the generators to the switchboard and feeder lines. Should the station be used for supplying current over long distances for light and power, it frequently becomes necessary to decide as to location of transformers, number and location of lightning arresters and method of carrying feeders out of the station; and if the plant be that of a manufacturing concern, information is often required as to the wiring of shops for light and power, the best method of supporting motors and starters and sundry other electrical and mechanical data which does not strictly appertain to the work immediately covered by the contract. The writer has learned by experience that it is advisable to impart such information freely to local engineers and electricians when it is called for and sometimes without being called upon, when the general conversation indicates that such information will be appreciated. At times it is necessary to volunteer information to insure a satisfactory installation from the standpoint of the manufacturer of the apparatus. One must be careful, however, not to imply that the informant knows it all. It must be borne in mind that many local engineers have not had the advantage of general observation and experience which comes from installing apparatus in many stations

of different construction; also that they are frequently familiar with local conditions, a knowledge of which would be of great value to the erecting engineer. Consequently there is often much to be gained by an interchange of information along these lines, not the least of which is the feeling of good fellowship and confidence which usually results.

Some of the various features requiring consideration by an erecting engineer in the equipment of a plant may perhaps be best given under the following classification:

1—Switchboard—Location, supports and instrument wiring.

2—Generator Cables—Size, method of support, terminals and connection to generator and switchboard.

3—Feeders—Size and method of support.

4—Lights—Location, number and kind.

5—Motors—Size, supports and method of drive.

6—Starters—Style and method of support.

7—Protective Apparatus—Fuses, circuit breakers and lightning arresters.

### SWITCHBOARD

The switchboard should be located so that all generator leads will be as short as possible, especially if the voltage is five hundred volts or less and where direct-current generators are to be operated in parallel and require leads of similar resistance. For high tension service the switchboard should be located with particular reference to safety, preferably above the engine room floor. The switchboard should be rigidly supported, using insulated braces if possible. If the angle frame is to rest on channel irons, the latter should be leveled and secured to the floor before erecting the panels. In placing panels care should be taken to get them level and plumb and to avoid leaving spaces between adjacent sections. When the panels are in place, the instruments and rheostats should be carefully mounted and correctly connected.

All small wires should be rigidly supported and all joints, no matter how small or apparently unimportant, should be well made. This can be accomplished by using the "Western Union" joint, which should be soldered and carefully taped. After the small wires are in place a coat of black shellac on all taped joints will add to their durability and appearance.

### GENERATOR CABLES

To determine the size of generator cables, the amount of cur-

rent, voltage, and distance between generator and switchboard must be considered, such a size being selected as to make negligible the drop in voltage between the generator and the switchboard. The cables can be placed in conduit or exposed as may be best adapted to the particular requirements of the station. In alternating-current systems it is impracticable on account of the inductive effect to carry each lead in a separate iron conduit. Whether the system be single or three-phase all leads should be in one conduit of non-conducting and non-inductive material. With a two-phase system the two leads of each phase can be run in one metallic conduit, one lead neutralizing the effect of the other. When laying conduit, bends should be eliminated as far as possible and those that are necessary should be of large radius. When cables fit tightly an application of powdered soapstone will make them slide through the conduit more readily.

The question of insulation must necessarily be given careful consideration and the kind used will depend largely upon the voltage and method of support. If cables are to be laid underground and exposed to extreme dampness, properly insulated cables with lead sheaths are necessary. In some localities the Underwriters' Rules will largely determine the insulation which must be used whether wiring is installed in conduit, moulding or open work. When wiring is exposed the insulators and supports should be rigid so that the cables may be put under tension. To make a satisfactory appearance, all wiring should be strung tight and straight and all bends made at right angles. Whenever possible on long spans of heavy cable, it is advisable to use strain insulators at each end with a turn-buckle at one end.

Cable terminals at both the generator and switchboard ends should be carefully soldered. To do this successfully remove enough insulation from the cable end to allow it to enter the terminal to the full depth of the hole. Clean the cable end and terminal thoroughly and then heat the terminal and fill it with solder. The cable end should be heated at the same time and tinned in a pot of solder. Then the cable end should be inserted in the terminal, particular care being taken to see that the terminal, cable and solder are sufficiently hot to make a perfect joint.

### FEEDERS

After selecting the proper size of feeder the best means of support should be decided upon. The most modern and satisfactory method is to place all feeders, within buildings, in conduit, but on

account of the extra cost for this class of work open work is frequently used. It can usually be installed in such a way as to give satisfaction except under certain conditions. Reference to the Underwriters' Rules will show, for instance, that open work is largely prohibited in cellars or elsewhere below street levels.

### LIGHTS

The size of wire used in buildings can be considerably reduced by allowing for a slight drop in voltage between the switchboard and the point of consumption. An allowance of five per cent is not excessive and is advisable in most cases, when generators can be operated at a voltage to provide for such a drop and thereby maintain the voltage required at motors or lights.

The illumination of buildings is an art in itself and to secure ideal results requires much study and observation. The erecting engineer has, at least, had the advantage of observation and can therefore advise as to the proper placing of lights for particular purposes, after having found that certain methods give satisfaction in other buildings under similar conditions.

### MOTORS

The number and sizes of motors to be installed is generally disposed of at the time of placing the order for the generators. Subsequent units, however, are frequently required and the erecting engineer may be called upon for information in regard to them. The horse-power required to drive a given amount of machinery is always an uncertain quantity and to determine this it is well to make an actual test, using any motor of sufficient capacity that may be available. The tendency in most cases is to figure too closely, thereby keeping down the first cost but providing a motor too small for the purpose. Undue overloading of a motor has proven to be poor economy on account of the frequent repairs and the resulting expense and loss of time.

The method of drive and distance between centers is an important factor and deserves careful consideration. Should the distance be too short for proper belt surface on the pulleys, chain drive or gears can frequently be used to advantage.

### STARTERS AND CONTROLLERS

The starter or controller required for a given motor will of course depend upon the characteristics, style and size of the motor and the purpose for which the motor is used. The controlling ap-

paratus should be rigidly and securely installed and readily accessible.

### PROTECTIVE DEVICES

It is advisable to use a switch and circuit breaker, or the two combined, to properly limit the current and protect the apparatus. This arrangement obviates delay due to the replacing of fuses at times of excessive overload. Although the first cost of a circuit breaker is greater than that of fuses, yet in the long run the former will generally be found to be the most economical.

### LIGHTNING ARRESTERS

When current is carried from or to buildings over aerial lines, lighning arresters should be used as a means of further protection to generators, switchboard, motors, lights and buildings. There are various types of apparatus on the market to suit the requirements of the different kinds of service, their selection and adjustment depending upon the voltage and capacity of the system and local conditions. The nature of the soil available for the ground connection, the immediate surroundings of the line especially as to other wires and the probable extent of the lightning discharges should be carefully considered.

### SYSTEM

Much has been said and written with reference to the subject of systems and too much stress cannot be laid upon its importance. It is essential to efficient management and workmanship regardless of the nature of the work or business. In supervising the installation of the machinery in a power plant, the erecting engineer must first turn his attention to the calculations. Drawings and schedules covering apparatus and material to be installed must be prepared and a plan carefully thought out as to the method to be followed in placing the apparatus. The work can then be done more effectively in every particular and will invariably effect a saving of labor and material. If the work is properly systematized the personnel of the management or working force can be more or less changed without serious results and this is especially desirable in the case of an electrical installation where the engineer in charge is liable at any time to be called away or detailed elsewhere. His successor can under these conditions continue the work with comparatively little difficulty.

# NOTES ON CARBON BRUSH HOLDERS*

C. B. MILLS

ALL carbon brush holders for either alternating-current or direct-current machines may be divided broadly into two classes:

1. The sliding type or that in which the carbon is held or guided in a fixed position by means of a retaining box. As the name implies this form of holder permits free movement of the carbon radially.

2. The clamped type, or that in which the carbon is bolted or clamped rigidly to a pivoted support.

In general either type may be used in the various classes of

TWO FORMS OF THE SLIDING TYPE OF BRUSH HOLDERS
The one on the left made by the Westinghouse company, the one on the right by the General Electric company.

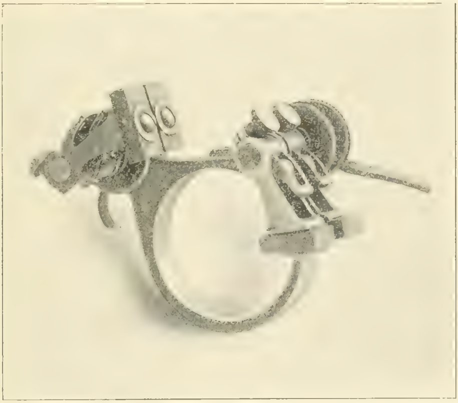
service for which machines are used, but there are certain distinct advantages and disadvantages inherent in both types which make them particularly adaptable to different lines of work.

The sliding type finds its greatest field in motor work. This is due principally to the ability of this type of brush holder to operate for long periods without attention, and also to the fact that it is not necessary to change the brushes when the direction of rotation of the armature is changed. These two features alone make this type of holder the more desirable for practically all railway work. The small inertia of the carbons or moving parts in this type enables the brushes to keep in intimate contact with the col-

*An extract, revised by the author, of a talk before The Electric Club.

lector rings, and makes this style of holder particularly adaptable to high speed work.

Against these good points should be balanced the facts that sliding holders are sometimes noisy in operation, although in many cases this can be overcome by inclining the carbons slightly. Carbons have a tendency to stick in the brush holder boxes when they become dirty or if the fitting has been poorly done. The drop through the brushes is in general higher than in the other type. To improve the conductivity, carbons in sliding type holders are usually shunted or provided with cable clips to carry the current from the carbon to the body of the holder; and for reliable opera-



A FORM OF THE CLAMPED TYPE OF BRUSH HOLDER
Made for the Northern universal motor

tion this is very necessary, especially where the current density in the brushes is fairly high. Different schemes of fastening clips to the carbons are employed. In one form the clips are soldered directly to the copper plating on the carbon. This method is quite successful and it is especially applicable to small carbons in which it is impossible to provide a suitable mechanical fastening. On the larger sizes, however, the bolted clip has been found the most satisfactory for carrying heavy currents. An important feature on all types of shunt fastenings is the copper plating on the carbons as practically the whole efficiency of the shunt depends on the continuity of the coppered surface.

To provide pressure for forcing the carbons against the commutator, sliding holders are usually provided with a spring of some form of the flat clock-spring type, as this form gives an even pressure throughout the range of motion of the carbon. Means are usually provided for varying the tension in the spring to suit different conditions of service. A pressure of one and one-half to two pounds per square inch of carbon will generally be ample, but different considerations of operation will require varying pressure for best operation. The heavy service of railway motors, for instance, requires that practically twice as much pressure be used as on ordinary motor work.

Carbon holders of the clamped type generally find their best application where it is necessary to carry relatively heavy currents, as this type of holder has higher current carrying capacity owing to its conductivity being improved by bolting or clamping the carbons to the main part of the holder. With very small carbons this type permits of a cheap construction with relatively high efficiency. In the larger sizes and especially for use on collector rings on alternating-current machines, its advantage in carrying capacity is very valuable. For commutator service it is inherently defective owing to the great inertia of the moving parts. When made up in small units, however, this defect is largely obviated and various modifications of this type have been largely adopted by European manufacturers.

Carbon as used for commutator brushes is made of a mixture of powdered coke and graphite with a trace of parafine for lubricating purposes, the exact proportions varying with the different manufacturers. As generally made the mixture is compressed into large slabs of practically the required thickness, and these slabs are then baked in a retort and afterward milled to the required thickness. As it is very important that the carbons fit closely in the holders, each individual carbon is tested for thickness and must be at least .002 inch thinner, and not more than .010 inch thinner than the opening in the holder it is to fit into, or it is rejected. The width is allowed to vary one thirty-second of an inch, as in this direction close fitting is not so important.

# CANADA AS A FIELD FOR THE ELECTRICAL ENGINEER

CHARLES F. GRAY

Superintendent of Construction, Canadian Westinghouse Company, Limited

THIS American continent is large, but at the present time the stretch of country north of the forty-ninth degree of parallel known as British North America is perhaps the foremost in the world in its openings to the man of energy. Blest with a fine climate and a very productive soil, embracing in its arms a continual flow of humanity eager to wrest from nature its health giving resources, the country is slowly but surely being filled by masses of people whose whole aim is to "get on." Such a concentrated mass of energy cannot fail to bring in its train the usual demand for labor, mechanics, skilled artisans and engineers to combat with conditions and overcome the difficulties always to be met with by the pioneer.

Electricity is now playing an important part in the development of Canada. In many of the provinces coal is high priced but nature has come to the aid of the settler and provided some of the finest water powers in the world. Most of us have heard of and perhaps seen the huge power plants now running and in course of construction at Niagara, but not many, outside of those who know the country, have the slightest conception of the immense inherent resources of this vast land. British Columbia alone, is blest with the finest water powers, for a country of its size, in the world; untold wealth in its mineral resources and coal is now being discovered; and, if you doubt its timber resources, go along the shores of Puget Sound and see the number of vessels of all nations loading British Columbia lumber. All winter long the woodman's ax can be heard ringing far up into the wilds and in the spring a continuous stream of tamarack, pine, cedar and hemlock is flowing to the coast to be shipped all over the world. The directors of many of the concerns handling the money making resources of the country realize the saving to be gained in production by the use of electrical energy and so a great many power plants are being built and projected, and the demand for electrical engineers is advancing.

The writer has in mind one plant which a few years ago was

of about 6 000 hp capacity. Now the total capacity of the plant is about 30 000 hp and the voltage has been increased from 20 000 to 60 000. This may not seem large when compared with the colossal schemes around Niagara, but when one remembers that this is only one instance of many and compares the small population of British Columbia with the two millions in Ontario, it will be seen that the internal resources must be great indeed to allow of such developments. The territories are opening up and, although Kipling in one of his poems states, "There's never a rule of God or man rules north of fifty-three degrees," the Northwest mounted police keep very good order, and business men have as much protection there as anywhere else. Saskatchewan, Alberta, Manitoba, Ontario, Quebec and the maritime provinces are all evidencing a desire for electrical development, and the need for men with initiative is growing.

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# A FAULTY MOTOR CONNECTION

J. E. LATTA

Associate Professor of Applied Electricity, University of North Carolina

FEW electric circuits are less complex than that required for supplying power to a shunt-wound, direct-current motor, nevertheless it is not an unusual occurrence for even an experienced electrician to fail to make the connections properly in putting such a motor into a circuit.

For example, in a former issue of the JOURNAL an engineer tells of a case where he was called on to inspect a motor that was taking excessive current at starting. In this case it was found that the circuit from the line to the motor was arranged in such a way that the starting resistance, before it was cut out of the armature circuit, was in series with the motor field. The mistake just mentioned is seldom made when the common form of starting box is used, as these boxes are usually marked by the manufacturer in such a way as to leave no doubt as to where the armature and field leads should be placed.

There is, however, a circuit frequently made in attempts to start shunt motors which is quite as faulty as the one referred to above. With certain types of motors this connection is so much

like the correct circuit in appearance that the operator is often very much puzzled when a machine connected up in this way fails to start properly. Fig. 1 shows a diagram of connections for a correct circuit for supplying power to a shunt motor. This circuit is correct regardless of which side of the power lines is positive. By reversing the connections at the armature terminals the circuit represented in Fig. 2 is obtained, which is a diagram of the faulty circuit referred to above. In starting a direct-current motor it is the usual practice to make sure that the field circuit is completed before any current is put into the armature. A motor connected as shown in Fig. 2 will show the normal field, but when an attempt is made to bring the

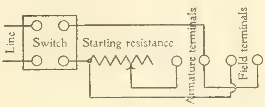


FIG. 1

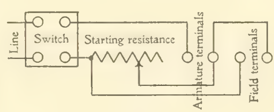


FIG. 2

motor up to speed the armature will run at a dangerously high speed and may "buck over" at the commutator before the starting box lever has been rotated to the position of full-speed running. If the load at starting is very small, the motor may start even before the armature circuit is closed. An examination of Fig. 2 will show that the starting resistance and the motor field are connected in parallel. Hence as the starting resistance is cut out the field current is decreased until if the resistance is all cut out the field will be short-circuited. As the speed of a motor depends on the field strength, it is apparent why the motor runs too fast when an attempt is made to start it.

# COMPARATIVE SIZE AND SAFETY OF TURBINE-TYPE ALTERNATORS

ALBERT KINGSBURY

THE most prominent feature of high-speed turbine-type alternators as compared with engine-type alternators is the very small size of the former. It may be said in general that the weight of the turbine outfit is about one-sixth of the weight of the outfit of corresponding capacity driven by compound engines. A more detailed comparison may be made by taking the cases of a 3 000 kw turbo-alternator running at 1 500 r. p. m. and an alternator of the same capacity running at 75 r. p. m. driven by cross-compound condensing engines. In the particular units between which this comparison is to be made, the total weight of the turbine unit, exclusive of condensing apparatus, is about 160 000 lbs. The total weight of the reciprocating engine and generator without auxiliaries is about 1 200 000 lbs. The flywheel alone of the compound engine weighs 320 000 lbs., or twice as much as the entire turbine unit. The 37-inch hollow shaft of the reciprocating engine weighs 130 000 lbs., or nearly as much as the entire turbine unit and has very nearly the same diameter as the rotating field of the turbine generator, and a section of this shaft 50 inches long represents the entire volume of the turbine generator field; or again the 16-inch hole in the shaft of the reciprocating engine represents very closely the volume of the rotating field of the turbine generator. In fact, this 16-inch hole will contain enough rotating fields as built for 300 kw turbine generators to make up the 3 000 kw nominal capacity of the unit.

It has sometimes been supposed that the high speed of rotation of the turbine generator field must render the machine a comparative-dangerous one; however, a little consideration will show that the reverse is true. The rotating parts are designed with about the same factor of safety as exists in the best designs of flywheels for reciprocating engines, and with a much better factor of safety than the average flywheel. Moreover, the rotating part of the turbine-type generator is contained in a thick shell of laminated steel which is exceedingly tough and capable of absorbing enormous shocks. In case of fracture of the rotating field, it would scarcely be possible for any of the parts to penetrate the stationary laminations. Again, the rotating part is small compared with the flywheel of the corresponding recipro-

cating engine, and even if the revolving field were not encased in the protecting stationary parts, the damage which it could do in case of explosion would be comparatively less than that of the corresponding slow-speed flywheel. It is well known that these flywheels sometimes explode at normal speed when not carefully designed, and almost invariable explode if the engine "runs away," however good the construction may be, and the explosions generally result in great damage to property and frequently in loss of life also.

For a further comparison, it may be stated that the water in the boiler supplying steam to the turbine for one of these generators contains from fifty to one hundred times as much explosive energy as is represented in the energy of rotation of the generator field itself. These boilers, of whatever type, are subject to deterioration in use and require constant care and watchfulness on the part of the attendants to insure safe operating conditions. The factor of safety as regards strength of shell or of tubes is no greater than that which is maintained in the design of the rotating field of the turbine generator; yet we have become accustomed to the boiler, and seldom give more than a passing thought to the power of destruction that it contains. This may be partly because there is less external evidence of the existence of this energy than there is in the case of the turbine generator.

For all reasons it appears that the turbine-type generator is not an element of additional danger in the modern power house, but rather gives a greater degree of safety than existed in the type of power house common five or ten years ago.

# THREE-PHASE POWER MEASUREMENT

H. M. SCHEIBE

THE fact that the power delivered to a three-phase circuit may be measured by two wattmeters is a matter of considerable importance and everyday application. The truth of the proposition, however, is usually demonstrated by mathematical treatment which, while conclusive, does not always give a practical understanding of what takes place.

It is the purpose of this article to offer a demonstration devoid of mathematics and applicable to any condition of unbalance of current or voltage. The proper connection of the meters is shown by Fig. 1 in which a delta connected receiving circuit is assumed. The indications of the meters may be considered as made up of two parts, one due to phase *A* and *B* and the other to phase *C*. For clearness each part is dealt with separately, and the diagrams show only those circuits being considered at the time. Figure 2 shows phase *C* omitted.

It is evident from this diagram that the power used in *A* and *B*

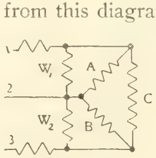


FIG. 1

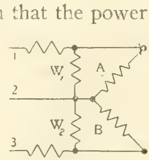


FIG. 2

will be indicated in meters $W_1$ and $W_2$ respectively, as *A* and *B* are simply two single-phase circuits with meters properly connected for reading single-phase power. Obviously then the sum of the effects of *A* and *B* on the meters will indicate the amount of power consumed in those two phases.

Having seen that the power consumed in *A* and *B* is recorded by the meters the separate effect of *C* may be considered. Fig. 3 shows this part of the circuit, but before dealing directly with this case, assume as a preliminary step the connections shown by Fig. 4. Here the junction of the pressure coils of the two meters has been disconnected from line *2* and it is evident that now *each* meter is connected to measure the power used in *C* except that the pressure coil of the other meter is in series with its own. This corresponds to connecting in a multiplier, and the indication of each instrument is re-

duced in proportion to the voltage across its pressure coil. So each meter will register a portion of the power in $C$ depending on the proportion of the drop across $C$ that takes place in the pressure coil. And, as the total drop in the two pressure coils must be the same as the drop across $C$, it follows that the sum of the effects of $C$ on the two meters must represent the whole power consumed in $C$. This may be most clearly realized by considering *instantaneous values of voltage, current and power.* By this means simple direct-current reasoning can be applied for any particular instant and the complexity of vector treatment avoided.

Reverting now to Fig. 3, in which the junction of the pressure coils is connected to line 2, it will be seen that while this connection may disturb the division of drop, between the two pressure coils, it obviously cannot effect the total drop at a given instant, as this is, as before, equal to the drop across $C$. Hence it follows that the con-

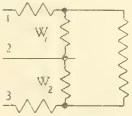


FIG. 3

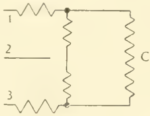


FIG. 4

nection to line *2* may effect the distribution but not the sum of the effects of $C$ on the two meters.

It has been shown above that the sum of the effects on the two meters due to $A$ and $B$ measures the power in $A$ and $B$ and that the sum of the effects due to $C$ measures the power in $C$. Therefore it follows that the sum of the combined effects of $A$, $B$ and $C$ must indicate the total power consumed in the three phases.

The foregoing has dealt entirely with a delta-connected circuit. The treatment, however, has been suited to any possible condition of voltages and currents on the three line wires, and it is these voltages and currents that determine the readings of the meters. Therefore this demonstration is applicable to all line conditions, regardless of the nature of the receiving circuit.

# EXPERIENCE ON THE ROAD

S. L. SINCLAIR AND E. D. TYREE

## METHOD OF DRYING OUT ELECTRICAL APPARATUS WHICH HAS BEEN SUBJECTED TO FLOOD

THE power house of a large Eastern manufacturing concern was recently flooded with water to a height sufficient to cover the two turbo-generators, two-thirds of the switch-board and a large part of the auxiliary apparatus, including the exciter units and the condenser pump motors.

The writers were called upon to get the plant in operating condition again with the least possible delay. Upon arriving at the power house it was found that the employees of the local company were attempting to dry out the generators by the use of a steam coil enclosed in an air flue. A blower was connected at one end of the flue and the other end opened at the generators so that hot air could be blown through the generator windings. This method would have taken an indefinite time to dry out the generators. It was therefore abandoned and an enclosure of sheet iron and tin, that was found around the works, was built up around the generators. Inside of this enclosure were placed a number of charcoal furnaces made of powder kegs. Thermometers were suspended near the generators and the temperature inside the enclosure was maintained at 85 degrees C.

While the generators were being dried by this process a small hoisting engine was belted to a 20 hp motor for use as an exciter. Arrangements were also made with the local railway company to furnish 500 volt direct current for making tests of insulation resistance. Insulation tests were made with a 600 volt direct-current meter having an internal resistance of 85 000 ohms.

After the generator had been drying for thirty-six hours the insulation resistance was about half the normal value. The generator was then started on a short-circuit heat run, and at the expiration of thirty hours, making sixty-six hours in all, the readings showed that the insulation was thoroughly dry and the generator was ready to go into service.

The second generator was dried in the same manner, with

the same results. The motors, exciters and switch-board were dried by the use of charcoal furnaces.

### AN UNUSUAL OPEN CIRCUIT

The generator on one unit continued to operate satisfactorily with the regular load. After several days we took occasion, while the machine was at rest and we were making insulation tests, to test the field circuit for continuity, and found the circuit open between the collector rings and within the fields. As this test was made shortly after shutting down the machine at the end of the regular run, there was no reason to suppose that a defect existed. Assuming that the circuit was closed by centrifugal force, the machine was again started and upon reaching a certain speed below normal the circuit closed. Further investigation showed that one of the connections between the field coils had broken, but when in operation the two ends came together and made sufficient contact to carry the necessary exciting current.

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## BOOK REVIEW

"Report of the Electric Railway Test Commission," to the President of the Louisiana Purchase Exposition. 600 pp; illustrated; McGraw Publishing Co.

This report covers the results of two years' work in investigation and test of the laws of electric railway operation. A concrete idea of its contents is given in the following statement, which is condensed from a review of the work by H. H. Norris and B. V. Swenson in the Electric Railway Review. These gentlemen were closely identified with the tests.

The first step taken by the commission was the appointment of four engineering committees, as follows: Test of City and Suburban Equipments, Test of Interurban Equipments, Test of Heavy Traction Equipments and Test of New Electric Railway Systems.

The tests as actually carried out comprised as many of the suggested investigations as it was practicable to perform. The number of separate and distinct tests actually carried out was sixty-one and many of these involved a large number of individual tests.

The train and air resistance investigations, including the preparation of the plans, the performance of the experiments and the working up of the data, covered a period of nearly two years.

The major portion of the work was devoted to problems connected with the movement of rolling stock. Naturally, this involved studies of acceleration and braking, together with tests of cars under service conditions.

Acceleration Tests—With a light city car it was found practicable to use an average acceleration of 1.33 miles per hour per second with a maximum accel-

eration of 2.5 miles per hour per second. This rapid acceleration, however, entailed a considerable strain on the equipment. A maximum speed of 20 miles per hour in this case was attained in 287 feet, the elapsed time from the start being 14.5 seconds. Similar tests made with a heavy interurban car resulted in an average acceleration of 0.59 miles per hour per second, a speed of 38 miles per hour being reached in 2 540 feet, the elapsed time from the start being 62.5 seconds. The rate of acceleration in this case was dependent upon the automatic control system. The maximum acceleration for the interurban car was 1.55 miles per hour per second.

Braking Tests—The average results show that a light city car weighing 14 tons and running at a speed of 18 miles per hour, can be stopped in a distance of 115 feet with an average deceleration of over 2.5 miles per hour per second, the time consumed in bringing the car to rest being slightly more than seven seconds. A heavy interurban car, weighing 40 tons, can be brought to rest from a speed of 55 miles an hour, at an average deceleration of 2.4 miles per hour per second, during a period of approximately 23 seconds, and while covering a distance somewhat under 1 000 feet.

Service Results — A single-truck city car was tested on the tracks on the World's Fair grounds under a schedule designed to duplicate as near as possible the ordinary conditions of service corresponding to a schedule speed of 10 miles per hour with 6.7 stops per mile, the corresponding maximum speed being somewhat over 20 miles per hour. The energy consumed per car-mile in this case was 2.3 kilowatt-hours, corresponding to 160 watt-hours per ton-mile, the weight of the car being 14 tons. These service tests were made with both hand and magnetic brakes and no appreciable difference was noted between the two from the standpoint of energy consumption. A double-truck city car, weighing 22.5 tons, was tested in regular service. It was found that this service comprised an average schedule speed of 9.3 miles per hour with 4.5 stops per mile. The energy consumption here was 2.74 kilowatt-hours per car-mile, or 122 watt-hours per ton-mile, both these quantities being very uniform throughout the series of tests which covered both wet and dry track. The service tests on interurban cars were made on the lines of the Indiana Union Traction Company between Indianapolis and Muncie with a modern heavy car and trailer, the former weighing 40 tons and the latter weighing 22.5 tons. The average speed was slightly under 30 miles an hour, being greater between cities and less in cities. The energy consumption for the motor car alone was 3.3 kilowatt-hours per car-mile or 84 watt-hours per ton-mile, while with the trailer the kilowatt-hours per train-mile were 4.6 and the watt-hours per ton-mile were 73.8.

Air Resistance Test—The results of these resistance tests show values varying from a minimum of 12 pounds per ton at 20 miles per hour with the best combination of vestibules to 43 pounds per ton at 60 miles per hour with a poor form of vestibule. These tests give reference data for standard interurban cars and the tests were made under such a variety of conditions that they may be considered to represent average values.

While the train resistance tests were not as complete as the commission could have wished, the air resistance tests were carried out in great detail. For the purpose of separating the air resistance from the other elements of the total resistance, the special dynamometer car "Louisiana" was constructed.

The effect of the air resistance on the surface of the car body was found to be small compared with the head pressure, the tests indicating that at very high speeds the head pressure and rear suction comprise the major portion of the air resistance.

As a result of these tests the suggestion is made that high speed interurban cars should be constructed with a rather sharp front vestibule and a parabola-shaped rear vestibule, in order that the air resistance may be minimized.

Rail and Track Resistances — The power factor, the rail drop, the temperature and the ratio of the alternating current impedance to the direct current resistance were carefully determined. The results of the track tests corroborate the deductions drawn from the single-rail tests.

This summarizes in a general way the work of the Electric Railway Test Commission. It is felt that the results accomplished are but a beginning, as many railway problems still remain to be solved.

THE

# ELECTRIC JOURNAL

VOL. IV. FEBRUARY, 1907 NO. 2.

**Series Resistance and Transformer Wave Forms**

The oscillograms of wave forms given in Mr. Copley's contribution to this issue of the JOURNAL are interesting from several standpoints. They illustrate the conditions which may arise in the use of ordinary transformers and resistances and show the effects which may be produced under conditions which often arise in laboratory and commercial tests. The effects which are shown have to do with the influence of resistance in series with the primary of a transformer upon the wave form of the electro-motive force.

It is well known that the magnetizing current of a transformer, owing to the variation in permeability at different inductions, is not proportional to the impressed electro-motive force. When, therefore, a definite electro-motive force, such as the sine wave, is impressed upon the primary, the magnetizing current is of quite a different form. Conversely, if a current having the sine wave form is forced through the primary, the electro-motive force at the transformer terminals will not be of the sine form. On the other hand, the current which flows through an ordinary resistance has a wave form similar to the electro-motive force. When, therefore, a resistance is placed in series with the primary of a transformer, each element tends to exert its own preference as to the wave form of the current. The result is a compromise, which more nearly approximates the sine form as the resistance is relatively high as compared with the impedence of the transformer coil.

If the transformer is used for supplying a high voltage for testing purposes, the maximum electro-motive force, and not that idicated by the voltmeter, is obviously the important one. The ratio between this maximum and the voltmeter reading depends upon the wave form. Consequently, the voltmeter reading does not give a proper indication of the stress on the insulation under test if the wave form is varying and unknown. An adjustable resistance in series with the transformer varies the wave form as well as the volt-

meter reading, and, therefore, the adjustable resistance is not a satisfactory method of voltage adjustment in high-tension tests.

Several years ago I saw a report of the effect of varying induction in transformer iron upon the wave form. Curves differing considerably in form had been taken showing the wave form for various values of electro-motive force; say, at one-fourth, one-half, three-fourths and normal voltage. It seemed to me that the electro-motive force of the secondary must be almost identical with that of the primary, which, in turn, is the impressed electro-motive force; and, therefore, the secondary electro-motive force should practically agree in form with the primary or impressed electro-motive force, whether the electro-motive force be high or low. It occurred to me that quite likely the lower electro-motive forces had been obtained by placing a resistance in series with the primary for reducing the voltage. Upon inquiry it was found that such had been the case. The various wave forms, therefore, resulted from the introduction of resistance, a cause which had been quite overlooked in the conclusions which had been drawn. If the iron loss had been measured at different inductions when the voltage was adjusted by a resistance in series, the values obtained would have been quite different from those which would have been secured if the same effective voltages of the sine form had been applied.

Although the introduction of series resistance is a convenient means of securing low voltages for laboratory and testing purposes, it should be employed with great caution when the change in wave form is an important factor, as it is in measurements of iron loss or in high-voltage tests.

CHAS. F. SCOTT

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**Abstracts of Papers**

The proper method of making an abstract of a paper is not generally understood, and Professor Shaad's treatment of the subject should be of great assistance to all who undertake such an assignment, especially for acceptable presentation at a meeting. Where complete printed copies are in the hands of the audience, the hearers may be guided by references to the pages, so that any necessary explanation of the points presented by the abstractor may be readily grasped. The speaker may thus avoid any confusion between his own comments and the words of the absent author. If the abstractor is thoroughly familiar with the subject treated he can present even an abstruse paper in an interesting manner. Every printed

paper should be presented in abstract; and it was with this end in view that advance printing was introduced. Among those who have given the greatest satisfaction in this practice at Institute meetings are Dr. Nichols and Dr. Steinmetz. A great deal of time might be saved at these metings if the art of abstracting was more thoroughly understood. The subject is worthy of thorough discussion, and any assistance in the way of suggestions should bear fruit. A person who is deeply interested in a subject, however, is never entirely satisfied with an ordinary newspaper abstract. He will feel that some important point may have been omitted, but thankful for the necessary reference which will enable him to find the original.

RALPH W. POPE

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**Institute Membership**

The most gratifying growth of the application of electricity which has taken place in the past twenty years would hardly have been possible without the stimulus to systematize and publish new knowledge, the free discussion and emulation between workers, and the sense of pride and responsibility to the profession, which are largely due to the American Institute of Electrical Engineers. Few persons who have not had occasion to look at the matter in this light realize the truth and force of this statement. Non-members, and, indeed, many members as well, do not appreciate the great and beneficial influence which the society has upon the progress and standing of electrical industries and of its importance and dignity as the national body of the profession.

It is no ordinary occurrence that electrical industries and applications have advanced and the electrical profession has assumed so prominent and dignified a position in so short a time. The institute is one of the factors which has brought this about, and it promises to continue as an actuating influence not only upon the profession as a whole but upon its individual members.

A most definite and practical method of extending the influence and the utility of the institute is to bring into it new men. There are many electrical workers eligible to its membership who would strengthen the institute and receive individual benefit by joining.

The ground for presenting the subject in this way is not merely the accessions to the lists of the institute for the mere sake of numbers, but it is to secure the added strength which comes from a large membership and the widened field of usefulness which will result.

Those now belonging to the institute who concur with these sentiments should take occasion to emphasize the broad significance of the institute in presenting its claims upon those who should make application for membership; and those who are non-members will do well to give serious consideration to the matter of making early application for admission.

The writer, who is chairman of the committee on increase of membership, has reviewed the situation carefully and has himself been impressed with the cogency of the sentiments which are above presented. PERCY H. THOMAS

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**International Society for Testing Materials**

The JOURNAL has already printed one of the masterly addresses relating to the testing of materials delivered by Dr. C. B. Dudley, president of the American Society for Testing Materials; and some mention has been made of the work of that society in this JOURNAL. The American Society is affiliated with the International Society for Testing Materials, although the objects and aims of the two are somewhat different. The work of the American Society is largely in the line of the preparation of specifications for the purchase of materials and in outlining methods of test, and also in preparing standard specifications and standardizing methods of testing, so that all who purchase or use the same class of material may make their tests on the same basis. The International Society does less in the way of preparation of specifications and more in the matter of studying methods of test and problems relating to the characteristics of materials of construction.

The fourth congress of the International Society was held at Brussels, Belgium, last September. This congress was attended by European engineers representing engineering interests of almost every class. The representation of England and America was very small, there being but seven Englishmen and three Americans present out of 600 members of the congress.

The proceedings of the congress are printed in English, French and German. The congress itself was held in the Palais des Academies, one of the government buildings. Questions relating to reinforced concrete, protection of metals, characteristics of iron and steel, brasses, bronzes, building materials in general, and many other problems were presented.

To an American it seemed rather strange to hear a paper read in German, with the discussion following in German, French and English, in turn. In almost any European country one may hear

half a dozen languages spoken in a single day, most continental Europeans speaking several languages besides their own. At one of the dinners given to the congress the writer noticed a gentleman sitting directly opposite at the table speaking successively to parties within easy speaking distance, in their own languages, in Russian, German, French, Swedish, and finally to the writer in almost perfect English. This gentleman was manager of a large industrial concern, and it was part of his business to be able to speak practically all of the European languages. At the beginning of the congress there seemed to be a decided aloofness on the part of the members —which might well be expected on account of the great variety of languages spoken by the delegates. Toward the end, each member seemed to be trying to get acquainted with every other member. The splendid entertainment provided by the Belgian government was largely responsible for the bringing together of the members in this way.

Excursions were arranged to the various mills, factories, power plants, large government works, etc., throughout the kingdom; and the best trains which could be provided by the Belgian State Railways were put at the disposal of the congress. Excursions to the John Cockrell works at Seraing, near Liege; to the government testing laboratories at Maline, and to the great docks which are being built at Bruges Zee, were especially interesting. At the John Cockrell works are manufactured all classes of steam machinery, gas engines, railway supplies, ship supplies, guns, armor, etc. This company owns very extensive coal mines and these were also visited. The government testing laboratories at Maline, established for the purpose of testing railway materials, are the best equipped of any laboratories of the kind the writer has visited. The great sea-wall at Bruges is a stupendous piece of work, nearly two miles in length and extending into the sea in a great curve. Provision is here being made for unloading and caring for eight great ocean liners at once.

The social features of the congress were not neglected. The most brilliant affair during the proceeding was the state dinner given by the burgomaster of the city of Brussels, followed by a splendid reception at the Hotel de Ville. The final excursion of the congress was made to the celebrated watering-place at Ostend, where a dinner and ball was given at the Kursal in honor of the visitors.

On the whole, the congress was a decided success, both from the amount and character of work done and from the social standpoint, due to the splendid entertainment provided for the guests.

C. E. Skinner

# RAILWAY SIGNALING—II

## ELECTRO-PNEUMATIC INTERLOCKING

W. H. CADWALLADER

AN interlocking system has been defined by the American Railway Association as "An arrangement of switch, lock and signal appliances so interchanged that their movements must succeed each other in a pre-determined order." The definition applies equally well to the mechanical and electro-pneumatic interlocking systems; the latter, however, possesses certain distinct advantages over the former, among the most important of which are the following:

1—It is fifty percent quicker in operation than the mechanical system, and at least ten percent quicker than any other power operated system at present in use, thus permitting extremely rapid train movements on congested tracks such as large terminals, elevated lines and subways.

2—The interlocking machine usually requires less than one-quarter of the space occupied by a mechanical machine for operating the same number of switches, locks, and signals, thus economizing in the size of the building or "tower" containing it.

3—As the small operating levers entail very little effort on the part of the leverman to manipulate them, and as less levers are required than in a mechanical plant, fewer levermen are necessary for the operation of large plants.

4—The space required for the pipe and wire lines between the levers and functions operated in mechanical plants can be used for other purposes where electro-pneumatic interlockings are installed, since the room occupied by the wire and cables between levers and functions is comparatively small, and where necessary these pipes and wires can be placed in underground conduits.

As an example of the foregoing the electro-pneumatic interlocking plant at the St. Louis Terminal of the Terminal Railroad Association of St. Louis may be cited. The machine for operating this plant which includes 44 double slip switches with movable point frogs, 65 single switches and 194 signals, is about 44 feet in length over all, and contains only 215 levers, of which 33 are not in use, being available for future additions to the plant; whereas, a mechanical plant to operate this terminal would have contained 528 levers, and been 245 feet long. Five levermen on the busiest shift

operate the electro-pneumatic machine, while not less than twenty men would have been required for a mechanical machine under similar conditions. The wires and compressed air pipes at the St. Louis Terminal are all placed underground, and are entirely out of the way, while, had a mechanical plant been installed, the Terminal Company would have had to purchase considerable extra land on which to run the connections.

### GENERAL PRINCIPLES

Briefly outlined, the electro-pneumatic interlocking system provides for the operation of switches, locks and signals by compressed air and their control by electricity. This is effected by applying pneumatic cylinders to all such functions, and admitting and releasing compressed air to and from these cylinders by means of valves actuated by electro-magnets which are energized from batteries or generators located in the operating tower, the circuits being controlled by the manipulation of the levers in the interlocking machine. The movements of the switches and signals are in turn repeated back to the machine levers through circuit controllers located at the switches and signals and operated by them, thus electrically locking and unlocking the levers as the position of the switches and signals may necessitate. By these means positive indications are given that the movements of the switches and signals at all times correspond with the positions of their respective levers.

### PRINCIPAL ITEMS

An electro-pneumatic interlocking plant includes the following:

1—The power plant, comprising the air compressors, cooling coils and reservoirs, the electric generators, switchboard and batteries.

2—The interlocking machine, comprising the operating levers, the mechanical locking, the electric circuit controllers, and the electric locks.

3—The operating tower, which contains the interlocking machine and such other devices as may be necessary for quickly communicating and obtaining information from other points. These are usually in the form of visible or audible indicators, telephones, and telegraph instruments.

The main battery and electric generators are frequently located in the lower story of the tower.

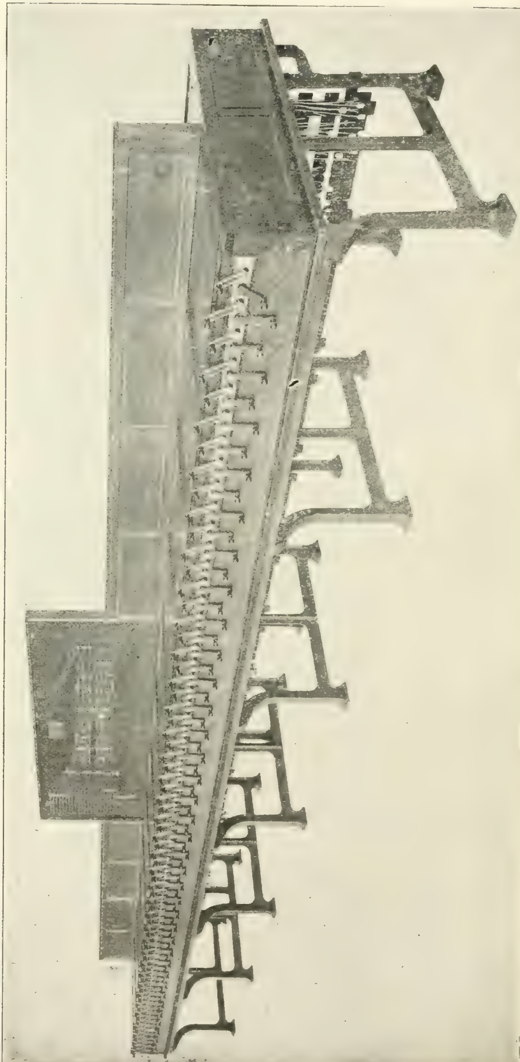

FIG. 1—VIEW OF ELECTRO-PNEUMATIC MACHINE IN TOWER NO. 1, ST. LOUIS TERMINAL

4—The pneumatic connections between the compressing plant and the switches and signals, and the electric connections between them and the interlocking machine.

5—The functions, under which term the switches, locks and signals are generally referred to.

6—The auxiliary appliances, such as track circuits for the automatic control of signals and locks, gateman's indicators, annunciators, etc.

### THE POWER PLANT

At practically all of the large terminals and at a number of other places where electro-pneumatic interlocking plants are in operation, compressed air is largely used for other purposes such as charging air brake tanks, cleaning cars and driving machinery. Consequently the pneumatic power for the interlocking plant can usually be taken from existing compressors. This air is first passed through cooling coils having a sufficiently large radiating surface to extract the heat generated by compression, and reduce the temperature of the air to that of the atmosphere before it reaches the main air pipe. Reservoirs of comparatively large capacity are placed below these cooling coils. These serve the double purpose of maintaining a reserve supply of air, should the compressor be stopped for a short time, and of collecting the moisture which has been condensed by the cooling coils. After leaving the cooling coils the air is conveyed by main pipes of from two to four inches in diameter through the entire system. The pipes are usually so arranged as to provide two paths by which the air can reach each switch or signal so that, in case of the breakage or stoppage of any pipe, the plant can continue to operate. Suitable expansion joints are provided to allow for variation in temperature.

From the main pipes, the air is conducted in smaller branch pipes to the switches and signals and at the end of each branch an auxiliary reservoir is located to catch whatever moisture may have escaped the main reservoirs. The main and auxiliary reservoirs are provided with cocks so that the water may be blown off from time to time.

The electrical power equipment usually consists of two small generators, driven by engines or motors, which alternately charge two sets of storage batteries of six or seven cells each, through a suitably designed switchboard. This equipment is located as convenience dictates, but as a rule, the batteries are placed in the lower

floor of the operating tower. The electrical power required by an electro-pneumatic plant is very small, the machine operating the largest plant in the world, St. Louis Terminal, Tower 1, requiring an average discharge of only five to six amperes.

INTERLOCKING MACHINE

The machine referred to in the preceding paragraph is illustrated in Fig. 1, from which a clear understanding can readily be had of its construction and method of operation. For the guidance of operators, especially when first learning the "combination" of large interlocking machines, it is customary to equip such machines with a miniature reproduction of the yard (known in signal parlance as a "Track Model") on which all switches and signals are

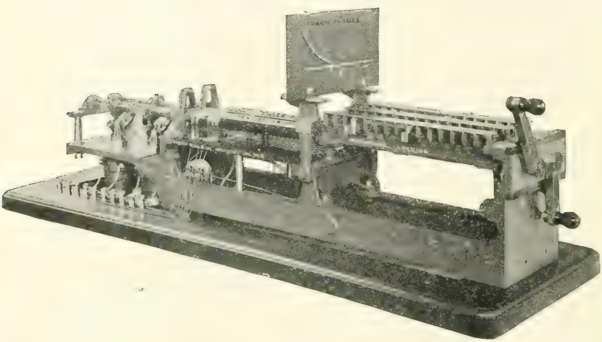


FIG. 2—SMALL MACHINE SHOWING MECHANICAL LOCKING, THE COMBINATION, THE INDICATION AND LOCK MAGNETS

numbered to correspond with the levers controlling them and all tracks are designated by their proper letters, names or numbers. The switches on this model board are connected mechanically to their controlling levers and move in accordance with them, thus permitting the operator to see at a glance the particular route or routes he has "lined up." On comparatively small plants having but few routes a track model is not necessary but on large and complicated installations it is of great assistance to the operators.

The operating levers point alternately up and down, those pointing upwards and having odd numbers being switch levers and the others signal levers. All machine levers are numbered from the left. Switch levers stand normally at an upward angle of 30 de-

grees to the left of the vertical, and when operated, are moved through an arc of 60 degrees. The normal position of signal levers is vertically downward from which they can be operated 30 degrees to the right or left, being capable of three distinct positions, the use of which will be explained later. A system of mechanical locks is provided between levers which is identical in every respect, except in size, with that described in a previous article treating of the mechanical interlocking machine. To each lever of the electro-pneumatic machine is secured a horizontal shaft, which performs three distinct functions. It drives the mechanical locking bars by means of racks and segmental gears; it rotates a hard rubber roller carrying phosphor bronze contact bands, thereby opening and closing the various controlling and selecting circuits for switches and signals; and lastly, it engages with the "indication latches" which are actuated by magnets, the energizing of which is effected by such switches and signals. Each switch lever is equipped with two such magnets, one known as the "normal" and the other as the "reverse" indication magnet, and each signal lever is equipped with one, known as the "lock" magnet. The object of these locks, or "indications" is to insure that the movement of each signal and switch shall correspond with the movement of the lever governing it. To the shaft of each lever a segment is attached for every lock, which engages with the latches of such locks and prevents the lever from being moved from one extreme position to the other until the switch or signal has responded to the preliminary movement and through circuit controllers closed the circuit of the "indication" or "lock" magnet, thereby lifting the latch from the segment and permitting the operator to complete the stroke of the lever.

Between the mechanical locking bed on the machine, and the bracket which carries the indication magnets, is a hard rubber plate. To this plate by means of screws are fastened phosphor bronze springs. These springs extend upward and bear against bronze bands on the hard rubber roller, and when it is desired to control a signal from one or more switch levers, the springs are made to bear against the rollers of the levers, and the bands on the rollers so set with relation to the position of the lever that the circuit may be opened or closed with the lever in any position desired. These springs form what is generally known as the "Combination." Fig. 2 is a top view of a small electro-pneumatic machine, and shows the mechanical locking, the combination, and the indication and lock magnets.

At the back of each hard rubber roller, on switch levers, is a short section of hard rubber mounted loosely so as to allow the switch lever to rotate 50 degrees of its stroke without being effected, but after the switch has responded to the first movement of its lever and been locked in its new position, the segment released and the lever now free to be put to its extreme position by the operator, the last 10 degrees of its stroke acts on the loose collar and closes two pairs of contact springs which are alternately closed in one position and open in the other. These springs form part of the controller

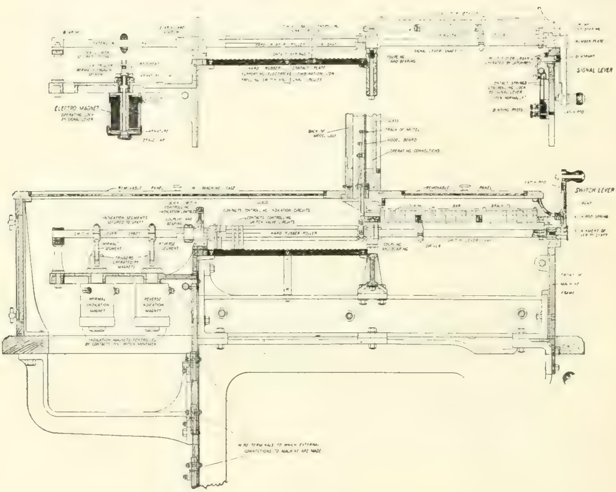


FIG. 3—SECTIONAL VIEW OF ELECTRO-PNEUMATIC INTERLOCKING MACHINE

circuit for the indication magnets. This loose piece is held from following the roller in its preliminary movement or from shifting by means of a toggle joint under the influence of a coil spring.

For the control of switches, five bands are mounted on the hard rubber roller (two of them being on the loose collar). For the control of signals two bands only are required. In addition to the regular bands on the roller, each signal lever is provided with a latch circuit controller which is normally open, and which closes a circuit on the lock magnet with the first movement of the latch, reasons for which will be explained later.

The electro-pneumatic machine is enclosed in an oak or walnut

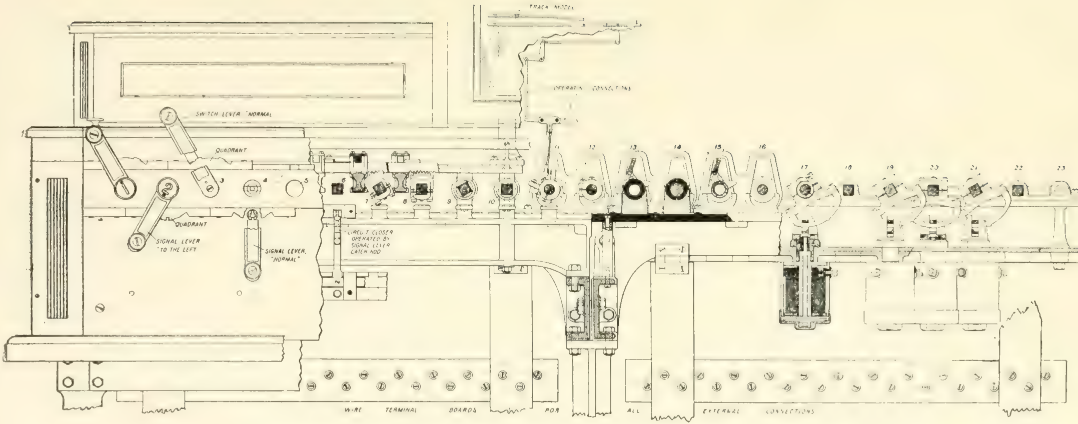


FIG. 4—SECTIONAL VIEW OF ELECTRO-PNEUMATIC INTERLOCKING MACHINE

**1**—Switch lever "normal" in elevation. 2—Signal lever "to the left" in elevation as used for clearing inward signals. **3—Switch** lever "normal" broken to show catch rod and quadrant. 4—Signal lever "normal" broken to show catch rod, quadrant **and circuit** closer crank. 5—Switch lever bearing only, in front plate. 6—Section of lever shaft under mechanical rocking bed. **7—Switch** lever shaft showing driver thereon engaging lock bar mounted in brackets. 8—Signal lever shaft showing driver **thereon** engaging lock bar mounted in brackets. 9-10—Intermediate shaft bearings under track model. 11—Section of switch **shaft through** coupling, and track model operating device. 12—Coupling on shaft of signal lever under track model. 13—Section **through rubber** roller of switch lever showing contacts of "quick switch." 14—Section through rubber roller of signal lever **showing** contacts of controlling signals. 15—Section through mechanism of "quick switch" in normal position. 16—Section **through** shaft bearing. 17—Section of switch indication magnet showing construction and arrangement of "reverse" segment. **18**—Section of signal lever shaft. 19—Elevation of switch indication magnet and "reverse" segment engaging it. 20—Elevation **of** signal lever lock magnet and segment on shaft engaging it. 21—Elevation of switch indication magnet and "normal" **indication** segment. 22—Section of signal lever shaft. 23—Elevation of rear bearing.

case, the top being covered with glass, enclosed in frames, so that the mechanical locking and combination can easily be inspected. Sectional views of the electro-pneumatic machine are shown in Figs. 3 and 4.

### OPERATING TOWER

This tower is usually two stories high, built of brick and of sufficient size to properly accommodate the interlocking machine, provide space for the operators, train director, telephones, telegraph instruments, etc. As previously mentioned, the machine is usually installed on the second floor, to enable the director and operators to get a good view of the tracks signalled.

In the tower, in plain view of the director and operators, are the annunciators, usually in the form of miniature signals enclosed in iron or wood cases, the blades of which are moved by rods connected directly to the armatures of vertical magnets. Working in connection with these annunciators, is a bell arranged to ring as the annunciators move from one position to the other, thereby notifying the operator of the approach of a train on the track which the annunciator indicates.

Fouling point indicators are also frequently used to indicate to the operator when a train has cleared the fouling point of a particular switch for his guidance in setting up routes for other trains. These annunciators are controlled through relays operated automatically by a section of track extending back to the fouling point.

(*To be continued.*)

# THE TECHNICAL GRADUATE AND THE MANUFACTURING COMPANY*

CHAS. F. SCOTT

THE changes which have occurred in the life-time of the young men of the present day surpass in many features those which have occurred during many centuries. The rate of progress, moreover, is an accelerating rate. The value of the manufactured products of the United States have doubled in value in less than twenty years. This is significant of a new order of things. Engineering is not only the basis of this material change, but it is also the underlying conditon which has brought about the new political, economic and social evolution. These facts are well known. They have come to be regarded as almost commonplace. It is important, however, that we realize their significance in order that we may better understand the present tendencies and anticipate the qualifications which the future engineer should possess.

Two institutions have grown up within the past few years, with which we are very intimately concerned. These are the technical school and the large manufacturing company. In engineering education the ideals, the methods and the facilities are all new. The engineering graduate is a new product. He is a new factor in the world's work.

Educational methods are not fixed and definite. They are vastly different from those of a generation ago, and the engineering educational methods of the near future may be quite different from those of to-day.

Closely related to this development in engineering education is that of the manufacturing company. In electrical engineering, in particular, the growth of the school and of the industry have had a close relationship. Each has been, to a greater or less degree, dependent upon and aided by the other. In the days of our fathers, manufacturing was carried on in a small way, usually one man was at the head of a given business, personally familiar with and directing its various departments. He devised processes, directed the manufacture and was his own sales agent. Modern manufacturing, however, is of a different kind. The various functions for-

*From *The Wisconsin Engineer*, based on a lecture delivered at University of Wisconsin, November 7, 1906.

merly performed by one man require the co-operation of many men in a single organization. Each is an expert, and altogether they act as a powerful unit.

Thus, co-operation—or the corporation—has become the modern method. It is the method, moreover, by which modern engineering is conducted. Enterprises, except those which are small or of a particular kind, cannot be conducted by a single individual. The co-laboration of many men is required for larger undertakings. Hence, the necessity of the engineer being able to work efficiently with others.

The large electrical manufacturing company is typical of modern manufacturing and business methods. It may be noted that the products of the electric companies, which are now produced in values exceeding a hundred million dollars a year, would have had no market thirty years ago, as they would have been practically useless. The work of these companies, in general, is broad in its scope; it includes invention, development, design, manufacture and erection, as well as the sales and financial departments. To carry on this work such companies are divided into many departments. Technical men find their field in those departments which are concerned with engineering, either directly or indirectly, and, furthermore, the engineering training is found in many cases to be an excellent preparation for those engaged in more purely executive work.

There was an old-time idea that the theoretically trained young man was completely equipped for doing engineering work and that he was at fault if he was not immediately prepared to produce efficient results. This view, however, is based upon several misconceptions. First of all is the relation between knowledge and experience. One may know his theory and his formulae, but engineering problems are not abstract, they are concrete. They deal not merely with forces but with materials. One must know the constants of his materials and the uses of the products. These come from experience. The designer of apparatus must not only know the theoretical principles which are involved, but he must know the various qualities, electrical and mechanical, of the many materials which he must use. He must be familiar with the methods of using these materials and the manufacturing facilities which will insure cheap and rapid production. He must be familiar with the service conditions so that he may design apparatus which will not only meet reliably the electrical and mechanical requirements of normal opera-

tion, but which will safely withstand the emergency conditions which are liable to arise. His apparatus must be adapted to the class of men who will use it. It must work properly with the other apparatus in the system in which it is to be placed. It must, in short, meet commercial conditions in a manner which will prove acceptable to those who purchase it. A gain of a percent in efficiency or in regulation is of minor consequence if a machine has bad bearings which overheat. It follows, therefore, that even the designer, who has probably more to do with theory than those in any other department, has to be familiar with many other points besides his theory. Experience, creative imagination, foresight as to the effects of new combinations and new forms, good judgment, integrity, not only with people but in dealing with facts, tact and the ability to get along comfortably and efficiently with other people, together with a goodly measure of all-round common sense, are qualities which must supplement the knowledge of formulae in order to effect the best results.

Those who are engaged in testing departments, in inspection, in erection, as well as in the various departments of commercial engineering and sales, require in a large measure the same breadth of view and qualities which have just been enumerated.

The manufacturing companies have recognized that the man immediately from college requires a further training. He needs experience, a new point of view. Engineering apprenticeship courses are therefore arranged in which he may gain familiarity with manufacturing and testing operations and also, what is of scarcely less importance, an immediate knowledge and acquaintance with the working together of many men in a great organization.

Young men in college are devoting their energies to preparation for their life work. It behooves them to expend their efforts as efficiently as is possible. They will do well first of all to learn fundamental principles, to gain theory not merely in the abstract but through their laboratory work to gain a concrete physical understanding of these principles. A knowledge of specific things, such as particular kinds of apparatus or the characteristics of special materials used in manufacturing processes, is of less consequence. Practice changes; principles do not. The student must not emphasize knowledge as distinguished from training. Training, which enables him to use his knowledge, is of first consequence. The man who is trained in observation, whose logical and reasoning powers are alert, who is able thereby to efficiently apply the knowledge

which he has, will probably be much more effective and successful than his companion who may know more but can do less. A skilful workman with poor tools can accomplish more than a mediocre workman with the best of tools. Many of those who select college graduates look for the successful leaders in student organizations rather than those who head their classes. The man who combines both kinds of leadership gives especial promise. Many students do not get this broader view of their work. They do not apply engineering methods to themselves. Each man may well consider himself as a machine, as something with which to produce results. He should study how he may produce the best results with the least effort. Many are already quite proficient insofar as the "least effort" is concerned. The real problem, however, is with reasonable effort to produce maximum output. It is probable that some who have seemingly expended but little effort have learned to work with greater efficiency than the plodders who have received better classroom reports but with a vastly greater expenditure of effort. The man who had learned to handle himself and to work efficiently has a vast advantage when he does apply himself. This is one reason why college grades do not give a true indication of future careers.

If students can take this larger, broader and more serious view of their work, giving attention to the understanding of principles rather than the knowledge of facts, and recognizing that the training in the use of their powers is of scarcely less importance than the acquisition of these powers, then the college graduate will become a more successful man both from his own standpoint and that of usefulness to others.

# LIMITING CAPACITIES OF LONG DISTANCE TRANSMISSION LINES

CLARENCE P. FOWLER

THE amount of power which can be commercially transmitted over a long-distance transmission line is usually limited by the voltage regulation. The voltage regulation is the drop in voltage caused by the transmission line. It is the difference between the voltage measured at the power house and the voltage measured at the receiving station, and is usually expressed as a percent of the normal voltage at the receiving station. The drop in voltage is dependent upon the resistance of the line, its inductance, the frequency, the current and the power-factor of the load.

The method of obtaining the resistance of the line is well known. The inductance at a given frequency depends upon the size of the conductors and their distance apart. The inductance volts for given conditions are found from tables, such as the one given on page 92 of the JOURNAL for February, 1906. The resistance volts and the inductance (or reactance) volts may be combined as two sides of a right angle triangle, the hypothenuse of which gives the line impedance. This represents the electro-motive force which would be required for sending the current through the line when short-circuited at the receiving end.

The effect of the above mentioned line conditions, namely, the resistance volts, the inductance volts and the power-factor of the load, upon its voltage regulation is given in Table I. It will be noted by an examination of this table that the total drop when the power-factor of the load is 100 percent is dependent almost entirely upon the resistance and very little upon the inductance of the line; whereas, at low power-factors the inductance is a very important factor in determining the total drop. This table, it may be remarked, is applicable not only to long-distance transmission lines using high voltage but also to all circuits which have both resistance and impedance, whether these elements be in the conducting wires themselves or in impedance coils or other devices.

At the 20th annual convention of the American Institute of Electrical Engineers in 1903, Mr. P. M .Lincoln presented a paper, entitled "Choice of Frequency for Very Long Lines." One of the elements which he takes up is the limit of power which can be transmitted over a given line without exceeding certain limits as to volt-

age regulation. He gives the limiting kilowatts which may be transmitted under definite conditions at a distance of 200 miles.

The method suggested by Mr. Lincoln has been worked out for a wider range of conditions and the results are given in Table II. In this table it is assumed that power is delivered from a three-phase line, that the conductors are six feet apart and equidistant, that the size of conductors is such as to give approximately 15 percent resistance loss, and that the power is delivered at 85 percent power-factor. If the size of wire be changed, the effect upon the inductance volts will be very slight,—for example, if the size of wire be increased so that the loss is reduced as much as 50 percent, the inductance volts will likewise be decreased, but only a few percent.

TABLE I

TOTAL DROP AT POWER-FACTORS RANGING FROM 60-100 PER CENT., WITH DIFFERENT PERCENTAGES OF RESISTANCE AND INDUCTANCE VOLTS, IN TRANSMISSION CIRCUITS

| Per Cent of Received E. M. F. | | Per Cent Total Drop for Power-Factors of | | | | | |
|---|---|---|---|---|---|---|---|
| Resistance Volts | Inductance Volts | 100 per cent | 95 per cent | 90 per cent | 85 per cent | 80 per cent | 60 per cent |
| 5 | 3 | 5. | 5.75 | 6.0 | 6.0 | 5.9 | 5.5 |
| 5 | 5 | 5.1 | 6.5 | 6.9 | 7.0 | 7.0 | 7.0 |
| 5 | 10 | 5.4 | 8.2 | 9.2 | 10.0 | 10.1 | 11 0 |
| 5 | 15 | 6.0 | 10.1 | 11.8 | 12.8 | 13.3 | 15.0 |
| 10 | 5 | 10.0 | 11.0 | 11.3 | 11.25 | 11.0 | 11.0 |
| 10 | 10 | 10.4 | 12.8 | 13.6 | 14.0 | 14.0 | 14.0 |
| 10 | 15 | 11.0 | 14.8 | 16.0 | 16.8 | 17.0 | 18.0 |
| 10 | 20 | 11.8 | 16.9 | 17.75 | 19.9 | 20.3 | 22.0 |
| 15 | 10 | 15.4 | 17.5 | 18.0 | 18.0 | 18.0 | 17.0 |
| 15 | 15 | 16.0 | 18.8 | 20.3 | 21.0 | 21.0 | 21.0 |
| 15 | 20 | 16.8 | 21.0 | 23.0 | 24.0 | 24.0 | 25.0 |
| 15 | 30 | 18.8 | 26.0 | 28.3 | 30.0 | 31.0 | 33.0 |
| 20 | 15 | 21.0 | 24.0 | 24.9 | 25.0 | 25.0 | 24.0 |
| 20 | 20 | 21.6 | 26.0 | 27.1 | 27.9 | 28.0 | 28.0 |
| 20 | 30 | 23.7 | 30.2 | 32.5 | 33.8 | 35.0 | 36.0 |
| 20 | 40 | 26.3 | 35.2 | 38.3 | 40.0 | 41.5 | 44.0 |

Mr. Lincoln in the paper above referred to makes the following statement with regard to charging current:

"Charging current is, of course, a direct function of frequency and voltage and, to a slight extent, of line construction. At 60 cycles the apparent energy represented by the charging current in a 200-mile three-phase line is practically equal to the ultimate capacity of that line as limited by the 20 percent inductance volts consideration. At 25 cycles it is only about 15 percent of the ultimate capacity as limited by the same consideration. In a 60-cycle instal-

TABLE II

APPROXIMATE KILOWATTS AT POWER-FACTOR OF 85 PER CENT; INDUCTANCE VOLTS 10, 15 AND 20 PER CENT; DISTANCE 50, 75, 100, 150 AND 200 MILES; LINE VOLTAGE, 20 000-100 000 VOLTS

| Distance and E. M. F. | 10 per cent Inductance Volts | | 15 per cent Inductance Volts | | 20 per cent Inductance Volts | |
|---|---|---|---|---|---|---|
| | 60 cycles | 25 cycles | 60 cycles | 25 cycles | 60 cycles | 25 cycles |
| **50 Miles** | | | | | | |
| 20 000 | 900 | 2 300 | 1 400 | 3 500 | 1 800 | 4 700 |
| 30 000 | 2 000 | 5 300 | 3 000 | 7 900 | 4 000 | 10 600 |
| 40 000 | 3 600 | 9 400 | 5 400 | 14 100 | 7 200 | 18 800 |
| 50 000 | 5 600 | 14 700 | 8 400 | 22 000 | 11 200 | 29 400 |
| 60 000 | 8 100 | 21 200 | 12 200 | 31 700 | 16 200 | 42 300 |
| 80 000 | 14 400 | 37 600 | 21 600 | 56 400 | 28 800 | 75 200 |
| 100 000 | 22 500 | 58 700 | 33 700 | 88 000 | 45 000 | 117 500 |
| **75 Miles** | | | | | | |
| 20 000 | 600 | 1 600 | 900 | 2 300 | 1 200 | 3 200 |
| 30 000 | 1 300 | 3 500 | 2 000 | 5 300 | 2 700 | 7 000 |
| 40 000 | 2 400 | 6 300 | 3 600 | 9 400 | 4 800 | 12 600 |
| 50 000 | 3 700 | 9 800 | 5 600 | 14 700 | 7 500 | 19 600 |
| 60 000 | 5 400 | 14 100 | 8 100 | 21 200 | 10 800 | 28 200 |
| 80 000 | 9 600 | 25 000 | 14 400 | 37 600 | 19 200 | 50 000 |
| 100 000 | 15 000 | 39 200 | 22 500 | 59 000 | 30 000 | 78 400 |
| **100 Miles** | | | | | | |
| 20 000 | 450 | 1 200 | 700 | 1 700 | 900 | 2 300 |
| 30 000 | 1 000 | 2 600 | 1 500 | 3 900 | 2 000 | 5 300 |
| 40 000 | 1 800 | 4 700 | 2 700 | 7 000 | 3 600 | 9 400 |
| 50 000 | 2 800 | 7 300 | 4 200 | 11 000 | 5 600 | 14 700 |
| 60 000 | 4 000 | 10 600 | 6 100 | 15 400 | 8 100 | 21 200 |
| 80 000 | 7 200 | 18 800 | 10 800 | 28 200 | 14 400 | 37 600 |
| 100 000 | 11 200 | 29 500 | 16 900 | 44 000 | 22 500 | 59 000 |
| **150 Miles** | | | | | | |
| 20 000 | 300 | 800 | 450 | 1 200 | 600 | 1 600 |
| 30 000 | 650 | 1 700 | 1 000 | 2 600 | 1 300 | 3 400 |
| 40 000 | 1 200 | 3 200 | 1 800 | 4 700 | 2 400 | 6 400 |
| 50 000 | 1 800 | 4 900 | 2 800 | 7 300 | 3 700 | 9 800 |
| 60 000 | 2 700 | 7 000 | 4 000 | 10 600 | 5 400 | 14 000 |
| 80 000 | 4 800 | 12 500 | 7 200 | 18 800 | 9 600 | 25 000 |
| 100 000 | 7 500 | 19 600 | 11 200 | 29 500 | 15 000 | 39 200 |
| **200 Miles** | | | | | | |
| 20 000 | 225 | 600 | 350 | 850 | 450 | 1 100 |
| 30 000 | 500 | 1 300 | 750 | 1 900 | 1 000 | 2 600 |
| 40 000 | 900 | 2 300 | 1 300 | 3 500 | 1 800 | 4 700 |
| 50 000 | 1 400 | 3 600 | 2 100 | 5 500 | 2 800 | 7 300 |
| 60 000 | 2 000 | 5 300 | 3 000 | 7 700 | 4 000 | 10 600 |
| 80 000 | 3 600 | 9 400 | 5 400 | 14 100 | 7 200 | 18 800 |
| 100 000 | 5 600 | 14 700 | 8 400 | 22 000 | 11 200 | 29 500 |

lation, therefore, it is necessary either to operate the generators on such a line at about full-current output all the time, no matter what

the load, or to compensate for the charging current in part or in whole by the installation of choke coils, either horn of which dilemma is not pleasant to consider. The problem of taking care of the charging current at 25 cycles does not enter the discussion as compared with 60 cycles.

"The effect of a large charging current on the regulation of the generator should also be considered. As is well known, a line charging current, when circulated in a generator armature, has the effect of assisting the field ampere turns to magnetize the fields. The percentage of magnetizing done by this charging current depends upon its amount and the inherent regulation of the generator. Since the charging current depends upon the voltage, the generator exciting power of the charging current also depends upon the voltage. The effect of sudden load changes, therefore, which tend to change the voltage delivered, will in turn affect this element of the excitation. That is, to a certain extent, the generator assumes the regulation which inherently belongs to a direct-current shunt generator. The effect of large charging currents on generator regulation is, therefore, not toward an improvement."

As the charging current of a line 200 miles long is practically equal to the ultimate capacity of the line, when the frequency is 60 cycles and the inductance volts are 20 percent, it follows that the charging current exceeds the normal working current when the inductance volts are less than 20 percent. For distances less than 200 miles, the charging current is proportional to the distance and the power delivered is greater than for 200 miles. Consequently, the charging current is considerably less than the normal current for the conditions given in the table, except those for the greater distances and higher frequency and the lower inductance volts.

# ABSTRACTING ENGINEERING PAPERS

GEORGE C. SHAAD
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THE increased number and greater activity of the local organizations of the American Institute of Electrical Engineers, as well as other of the national Engineering societies, draws attention to the question of the papers appearing on the programs of these local branch meetings. Original papers by members of each branch, especially if on some local topic or some subject of universal interest, are usually to be desired but, in many localities, the members who are capable of preparing such papers are busy men and a great deal of pressure must be brought to bear on them by the committee in charge of the program if articles of this nature are forthcoming.

We find, then, that for many of the meetings of a great number of the branches the most readily available material is in the form of the papers presented at previous meetings of the society proper, in fact it was to bring this material more prominently before the members residing at a distance from the headquarters that local branches were first organized, the A. I. E. E. sending out advance copies of the New York papers to aid the branch societies.

Obviously, with a few exceptions, for any one but the author to read these papers verbatim is not conducive to a large attendance at the meetings, to say the least, but if abstracts are carefully and properly prepared, interesting and well attended meetings are possible. Where a technical school is in the neighborhood of the local organization such abstracts may often be prepared by advanced student members and such preparation is of great benefit to students in an educational way, aside from bringing them in direct touch with their professional society.

In the preparation of the abstract of an engineering paper the writer of the abstract must be thoroughly acquainted with the subject as treated and with the character of his audience. The latter is necessary for the purpose of making clear any points that may be assumed as known by the author of the paper but which may be entirely foreign to many of the members at a local meeting. Not only should the article itself be carefully studied but any discussion by the main organization or other branches should be carefully considered. Not until thoroughly familiar with the entire paper and all available discussion and comments should the abstract be started and it should then contain, in general:

1—*All new, essential and especially interesting points brought out by the paper, arranged in logical order.* While this is the most important feature of any abstract and the sum and substance of most abstracts prepared for publication, it is also the most difficult one and the things to be looked for differ greatly with the nature of the paper. For illustration, assume that the article in hand is the description of a power plant. Few may be interested by a complete catalogue of the pieces of apparatus contained in the plant with their various ratings, though some idea of the total capacity and the nature of the machinery should of course be given. It is much better to take up such points as special arrangement of machinery to promote economy in floor space and operation, freedom of access, flexibility of operation; changes from standard practice along construction or operating lines with their object and, if possible, the results of such changes; features which have led to the reduction of cost; precautions taken to secure reliability of service; provisions for future extensions and so on.

Again, in the case of a paper dealing with the results of some test of a station or piece of apparatus, what is wanted most of all is the results of such tests. Are they below, equal to or better than what might normally be expected of such apparatus? If below, why so and how might the results be improved? If better, what is the cause of such improvement in performance? Also, what special advantages are shown and what conclusions may be drawn from the test in general?

Another type of paper may deal with the description of a new type of apparatus. Some of the points to be noted in the abstract of such a paper are:

Results of previous attempts along similar lines, and if not successful, why not?

The difference in principles involved, if any, from other machines used for similar purposes.

The design and construction details in so far as they are necessary to make clear the operation of the apparatus, or where they are unique features of the machine.

Advantages and disadvantages compared with similar apparatus or machinery for the same purpose in such points as first cost, simplicity, reliability, etc.

The present field and possible extension of the apparatus.

2—*Methods by which results are obtained or derived.* It is not desirable to give the actual derivation of results where long

mathematical formulae are involved or where extensive but well known tests are applied, but rather the general methods used and then, what is quite essential, the results expressed in both graphical and tabular form where feasible.

In the presentation of the paper a black-board or some suitable means of graphical representation and tabular arrangement of the final results of tests, costs, etc., is very essential. Where possible both the methods and results in the original paper should be checked up by the member making the abstract. This is especially profitable when students prepare the abstracts.

3—*Further explanation of the points on which the author has been a little vague or assumed previous knowledge,* where it is thought such explanation is necessary for the particular membership. Quite often a very large part of the abstract should, in this respect, be an original paper. It is in connection with this portion of the abstract that one must be careful to consider the probable audience. Most meetings are attended by engineers occupied with various classes of work and it is often impossible to make every point clear to all those present. There is, therefore, not much probability of erring in the direction of making explanations too simple. As a further example of what is meant by this, suppose some method of operation is being described which differs from what might be considered as standard, it is often desirable to briefly explain such standard methods of operation; when a new machine for a certain purpose is referred to it may add greatly to the strength of the abstract to consider a few other pieces of machinery used for this same purpose, if there is any chance that the audience, as a whole, is not familiar with them.

4—*Points brought out in previous discussions of the same paper,* either at the meeting at headquarters or at other branch societies, with the names of the members taking part in such discussions.

5—*Further comment or discussion* by the writer of the abstract preliminary to the general discussion to follow.

In many cases the abstract of the previous discussions and the opening of the general discussion may be assigned to another member.

# E.M.F. WAVE DISTORTIONS

## PRODUCED BY IRON IN ALTERNATING CURRENT CIRCUITS

A. W. COPLEY

IF A sine wave of voltage is impressed upon the primary of a transformer, the secondary circuit being open, the current resulting will be simply the magnetizing current of the transformer and it will not be a sine wave but a wave very much distorted. If a resistance be connected in series with the primary, the current wave form will be smoothed out and the voltage wave form across the transformer will be distorted. If the series resistance is high the current wave form may come to almost a sine wave while the voltage across the transformer is considerably distorted. If, however, the resistance is so low as not to affect the current flowing to any great extent, the current wave will be smoothed out only a very little and the voltage wave form likewise will be only slightly affected. An examination of the curves of e. m. f. across the transformer with and without the series resistance may not show visible

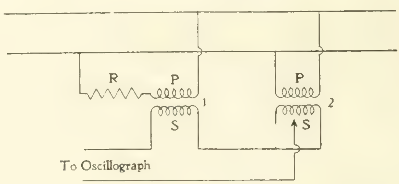


FIG. I

difference between them. However, harmonics are present and they can be separated out and their form seen by taking away the fundamental sine wave.

Practical demonstration of these facts was given by some recent tests in which two transformers were connected across a pair of mains having a 25-cycle sine wave of voltage between them. The first of the transformers had a resistance connected in series with it. The second transformer had a secondary coil with many taps so that the ratio of transformation could be varied in small amounts. The connections are shown in Fig. 1, the secondaries of the two transformers being connected in opposition to each other.

The secondary e.m.f. of transformer *1* was slightly distorted from a sine wave. while transformer *2* had a secondary e.m.f. of the sine wave form. By varying the ratio of transfor-

mation in transformer *2* the e. m. f. of its secondary was made equal to that on the secondary of transformer *1*. There was, however, a reading on a voltmeter connected in the circuit made up of the two secondaries connected in opposition. An oscillograph photograph of the two voltages—the voltage with the two secondaries in opposition and the voltage across transformer *2* alone—is shown in Fig. 2. The sine wave shown is the e.m.f. across the secondary of transformer *2* and the distorted wave is the resultant e.m.f. with the two secondaries in opposition. The two waves are not to the same scale, the distorted curve being magnified by reducing the resistance in the oscillograph circuit. It is seen from the

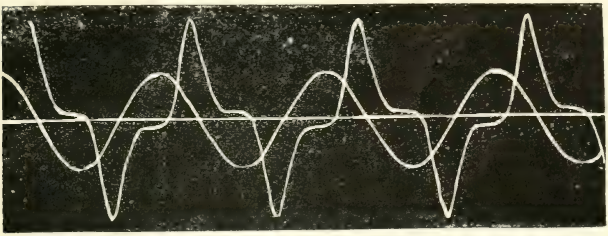

FIG. 2

curves that the two are approximately 90 degrees apart in phase. The distorted wave contains not only harmonics but also some of the 25-cycle frequency (that part of the e.m.f. on the secondary of one transformer which is in quadrature with the e.m.f. on the secondary of the other transformer).

To eliminate the main frequency, the e.m.f. wave on transformer *1* must be shifted in phase so that its phase is the same as that of the e.m.f. on the secondary of transformer *2*. This is accomplished when the power-factors of the two parts of the circuit, in which the transformer is, are made equal, *i. e.*, the power-factor of the series resistance must equal that of the transformer primary. Connecting non-inductive resistance in parallel with the transformer primary will raise the power-factor of that part of the circuit, or adding inductance to the series resistance will lower the power-factor of that part. Either one or both of these methods may be employed. When this is done and the reading of the voltage taken in the circuit made by the two transformer secondaries in opposition, this e.m.f. is found to be lower than before, but there is still a

voltage reading. The oscillograph photograph of the resultant e.m.f., Fig. 3, shows that the main 25-cycle frequency has been

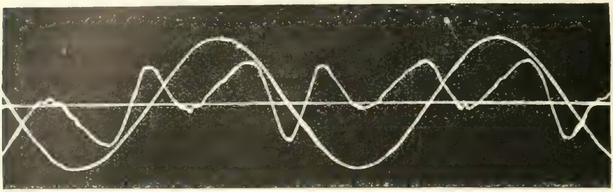

FIG. 3

practically eliminated and what remains is simply the higher harmonics which appear in the voltage of the first transformer. The value of the distorted wave in Fig. 3 is about one-quarter of that of the one in Fig. 2.

NOTE.—The oscillograph records in this article are reproduced, by permission, from the *Proceedings of the American Institute of Electrical Engineers.* The subject matter has been re-written by the author.

# POLYPHASE METERING CONVENTIONS

M. C. RYPINSKI

A KNOWLEDGE of the conventions followed by the manufacturer in the bringing out of leads and terminals on meters and meter transformers is often of great assistance in the making up of diagrams of connections and in locating the cause of trouble in existing installations. In arranging a set of instruments for metering a circuit, it is necessary not only to know what instruments are required and how they should be placed in the circuit but also how the circuit connections must enter the individual terminals of the instrument.

For instance, in a wattmeter one must be able to distinguish not only the potential terminals from the current terminals but also be able to tell the relative polarity of the two for positive indications of the meter. It is the purpose of this article to outline briefly some features of the Westinghouse apparatus bearing on the above matter.

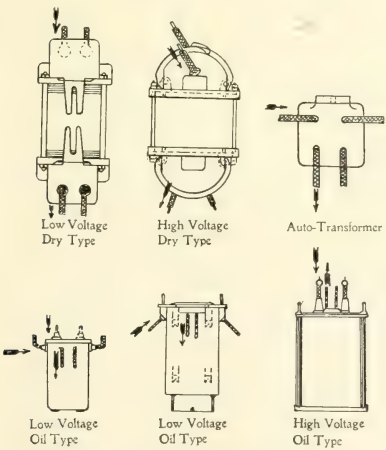

FIG. 1—VOLTAGE TRANSFORMERS

For example, the standard arrangement of polarity on the various types of voltage and current transformers for meter work is as indicated in Figs. 1 and 2. Assuming, in these figures, that the incoming arrows represent the positive direction of flow of current into the primary of the transformer then the corresponding outflow of current in the secondary is represented by the outgoing arrows.

It will be noted that the two leads so arrowed are always those most obviously related from a symmetrical standpoint. As an additional guide in selecting a set of corresponding leads they are given a coat of paint of a color distinctive from that of the rest of the apparatus. In the meters themselves a similar symmetrical arrange-

ment is carried out as may be seen by referring to Figs. 3, 4, 5 and 6, covering the standard round pattern switchboard indicating and integrating wattmeters, both single-phase and polyphase, in which the corresponding directions of flow necessary for positive indications are indicated by arrows. The light lines illustrate potential circuits and the heavy lines current circuits. In these and all following figures a rear view of the apparatus is indicated. The points at which the lines enter the various meters indicate the position of the terminals and it may be seen that the polyphase indicating wattmeters are back connected.

It is asumed that the reader is more or less familiar with the principle of operation of the various meters herein selected as ex-

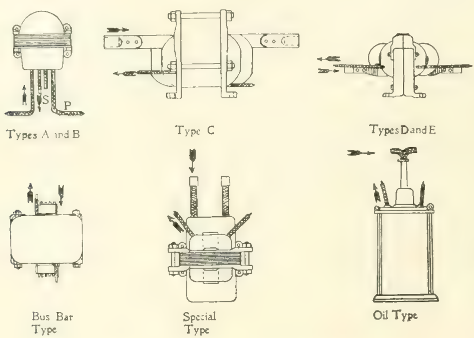


FIG. 2—CURRENT TRANSFORMERS

amples for consideration and no attempt will be made to cover any technical features.

It may be said, however, that the single-phase wattmeters involve one potential and one current winding, the polyphase meters two potential and two current windings (the corresponding terminals for each set being located one above the other). The single-phase synchroscope illustrated in Fig. 5 involves two potential sets of windings, the single-phase power-factor meter shown in Fig. 6 one potential and one current set of windings and the two and three-phase power-factor meter shown in Fig. 6 one potential and two current sets of windings.

The arrows on these figures indicate that with a given direction of flow into a potential terminal the direction of flow must be into

the symmetrically corresponding current terminal for positive indications. A reversal of either of these directions gives negative indications. A reversal of both gives positive indications again so that two conditions of correct connection exist with the single-phase

FIG. 3

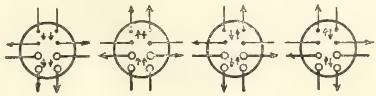

FIG. 4

meters and four conditions with the polyphase meters. The latter are illustrated in Figs. 4 and 6. In addition to the current directions corresponding it is necessary that the potential and current windings be connected to corresponding phases of the circuit before indications of correct magnitude can be attained.

In the polyphase wattmeters the convention is that a set of potential terminals must be connected in phase so as to correspond

FIG. 5

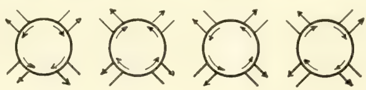

FIG. 6

with the current terminals directly beneath it. In the polyphase power-factor meter the set of potential terminals must be connected in phase so as to correspond with the left hand set of current terminals looking at the meter from the rear as indicated in Fig. 8. The single-phase meters must have their current and potential terminals corresponding in phase.

The single-phase synchroscope must have potential terminals

FIG. 7

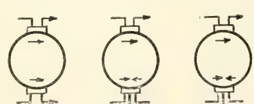

FIG. 8

agreeing in phase, see Fig. 7, whether used for synchronizing on single-phase or polyphase circuits and in practice the upper right hand terminal and the lower right hand terminal are connected in common. The application of the above conventions may be found in Figs. 9 and 10 where are illustrated a set of instruments connected

to the ordinary four-wire two-phase and three-wire three-phase circuits. Considering the primary current as having a positive direction of flow with the direction of power delivery in the legs which include series transformers and vice versa in the legs which do not include series transformers, the secondary directions of current flow may be determined. Knowing the latter and the conventions laid down above the various meters may be connected into the circuit with assurance that, barring an occasional error on the part of an

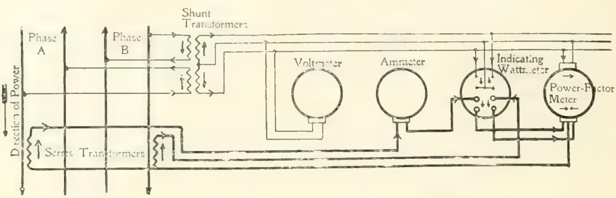


FIG. 9—DIAGRAM OF INSTRUMENT CONNECTIONS FOR A TWO-PHASE CIRCUIT

inspector testing for polarity, the meters will indicate correctly and in the right direction. The arrow heads on the connecting wires illustrate the various instantaneous directions of flow.

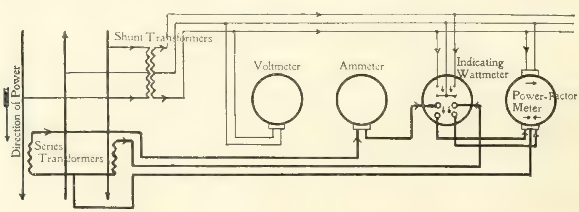


FIG. 10—DIAGRAM OF INSTRUMENT CONNECTIONS FOR A THREE-PHASE CIRCUIT

In Fig. 9, in order to assist in determining the secondary direction of flow, arrows are shown illustrating the 180 degree difference in phase between the primary and secondary current of the various transformers. In Fig. 10 these arrows have been omitted as they are not necessary in the tracing out of secondary flow if it is kept in mind that interposing a transformer does not change the direction of flow providing one goes from the primary to the corresponding secondary terminal.

# THE STANDARDIZING LABORATORY—III

## A POTENTIOMETER METHOD OF CALIBRATING STANDARD WATTMETERS

H. B. TAYLOR

POTENTIOMETER methods for calibrating ammeters and volt-meters are in common use and their advantages in precision measurements are quite generally appreciated. Their application to wattmeters is less common. The potentiometer being strictly a direct-current instrument, it obviously cannot be used in calibrating induction wattmeters or any other type of meter which does not operate as well on direct as on alternating current. There are two ways of applying potentiometer methods to the calibration of wattmeters. The one which would naturally suggest itself first is to take simultaneous readings of current in the series coil and voltage across the shunt. Another way is to measure the current in both series and shunt circuits. The latter method has been adopted for calibrating a certain type of standard alternating and direct-current wattmeter, and is better suited to that particular type than to others, but would need only slight modifications to make it suitable for general use.

### TYPE OF METER FOR WHICH METHOD WAS DEVISED

The wattmeters referred to are zero reading, and have circular scales, like Siemens dynamometers. Some have 200 and others 250 divisions. The divisions are engraved on the scales and are exactly equal. A vernier is provided for reading fractions of divisions. The normal shunt resistances of all meters are equal and are 1 000 ohms each for voltages in the neighborhood of 100 volts, or an even multiple of 1 000 for correspondingly high voltages. The greater part of the resistance is external to the meter itself, only 100 ohms being inside. As the external shunt resistances are equal and interchangeable for all meters, they are calibrated separately. The internal shunt resistance may or may not have been adjusted to exactly 100 ohms at the time the principal calibration is made, although it must be so adjusted before the instrument is complete.

### SPRINGS

The controlling force is transmitted from the torsion head to the movable coil through two spiral springs. Many of the details

in the illustration of this method, given below, owe their existence to the fact that the calibration of the springs constitutes practically the entire calibration of the instrument.

A spring does not exert a torque in exact proportion to its deflection, and the variations of torque do not follow any definite law. The custom of assuming that the current in a Siemens dynamometer is found by multiplying the square of its deflection by a constant, has been so long established that people have lost sight of the fact that the constant used can only be an approximation representing the average factor obtained from measurements at various points of the scale. The true calibration of a dynamometer often deviates as much as two per cent from readings calculated by means of this average factor. In an instrument which has to meet the requirements of a standard for calibrating other modern instruments an error of one-fourth that amount would be enormous.

Another source of variations in springs which is often overlooked is their change of strength with change of temperature. The torsional rigidity of probably all metals and alloys suitable for springs decreases as the temperature increases. The coefficient representing this change is, in nearly all instrument springs, somewhere between 0.00035 and 0.0006 per degree. The coefficients of the springs used in these wattmeters range from 0.00035 to 0.00045 per degree C., and are constant throughout the working range of temperature. The meters are calibrated at a temperature of 25 degrees C., or if the readings are taken at another temperature they are corrected to what they would be at 25 degrees.

## GENERAL PLAN

Two operators are required in calibrating, one of whom reads the wattmeter and the other the standards. The torsion head of the wattmeter is turned to some definite reading. Then, with 0.1 ampere in the shunt coil the current in the series coil is adjusted to produce the deflection for which the torsion head is set. The series current is then measured, the temperature of the meter noted and a point on the calibration curve located as outlined below.

Calibration curves are plotted between scale divisions as abscissae and corrections as ordinates. The vertical scale reads in divisions but is fifty times as large as the horizontal, in order that the exact correction may easily be read. In finding a point on the curve, the deflection and the two currents producing them are known.

One of the principles of electro-dynamics is that the force of attraction or repulsion between coils without iron, carrying currents, is proportional to the currents in the coils. In its application to electro-dynamometers this law is concisely expressed by the formula,—$F=Kii^1$, in which $F$ is the deflecting force, $K$ a constant, $i$ and $i^1$ the currents in the fixed and movable coils respectively. The formula may also be written $D=Kii^1$ in which $D$ represents the deflection of the springs if it is assumed that the opposing torque due to springs is proportional to their deflection. The latter assumption is taken as the basis of the calibration. It is represented by the straight line forming the horizontal axis of the curve. For the wattmeters under discussion the constant $K$ is predetermined. That is to say the springs must be adjusted so that a certain product of series and shunt currents will correspond to a certain deflection. The first step in calibrating a new meter is to adjust the springs to the right strength. It has been found best in practice to make this adjustment at the full-scale reading, as the later adjustment required to reduce the corrections at other parts of scale do not often affect that reading materially. The current in the movable coil and the constant $K$ being known, the value of the series current which should produce a given deflection may be calculated. If the current indicated by the standard is lower than that amount, the springs are too weak; if higher, they are too strong.

### APPARATUS

The standard instruments are placed on a table which is devoted exclusively to them and the necessary controlling apparatus used with them. All of the standard resistances are made of manganin. Low resistance standards of different capacities can be cut in and out of the series circuit by means of knife switches on a tablet at the operator's left. They are designed for 0.5 volt drop at full-load, except some of the larger sizes, which give only 0.25 volt. Potential leads from them connect through highly insulated wires under the table to metal tips on top of hard rubber posts behind the potentiometer.* A pair of flexible leads from it can be connected to any pair of the metal tips. Reversing keys are connected in all circuits except the one leading to the galvanometer. The apparatus used in measuring the current in the movable or shunt coil is simple; yet it

*This potentiometer was described in detail in THE ELECTRIC JOURNAL for December, 1906, p. 686.

is highly accurate and sensitive. It consists of a resistance of 10.195 ohms with connections from its ends, through a key and preventive resistance to a galvanometer and standard cell. A plug switch is provided for reversing the connections to the cell. The standard cell used is a Weston cell with an e.m.f. of 1.0195 volt. With the e.m.f. of the cell connected in the opposite direction from that across the resistance, the two will just balance and produce no deflection of the galvanometer when the key is closed, if the current in the resistance coil is 0.1 ampere. The galvanometer used is sensitive enough

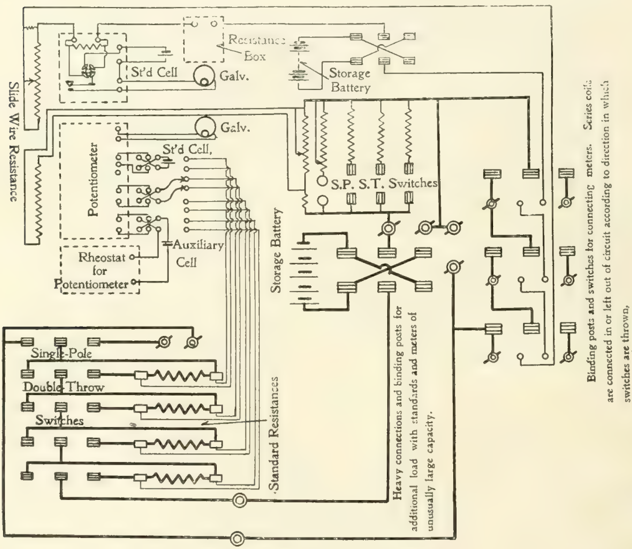


FIG. 1 DIAGRAM OF CIRCUITS

to give a visible deflection if the current is 0.001 per cent too high or too low. An arrangement of the controlling resistance allowing adjustment by exceedingly small steps enables the operator to maintain the exact value of current required. Fig. 1 is a general diagram of the circuits and Fig. 2 shows the arrangement of a standard table. The table is in a corner of the room with one end against a wall. Two galvanometers of the D'Arsonval type stand on a shelf against the other wall. Their scales are in a metal box above the table.

Two Nernst glowers are mounted in the back of the same box so that their light shines through vertical slots upon the mirrors and is reflected back upon the scales. The scales are slightly above the level of the observer's eyes when he is sitting down and far enough to his left to allow the beams of light to pass over his shoulder. Nernst glowers are used because they give a spot of light brilliant enough to be seen without darkening the room. Originally the glowers were mounted directly behind the slots, but so much difficulty was experienced in keeping them properly aligned that they were afterward mounted to one side and their light reflected through the slots by means of plane mirrors set at an angle and provided with adjusting screws.

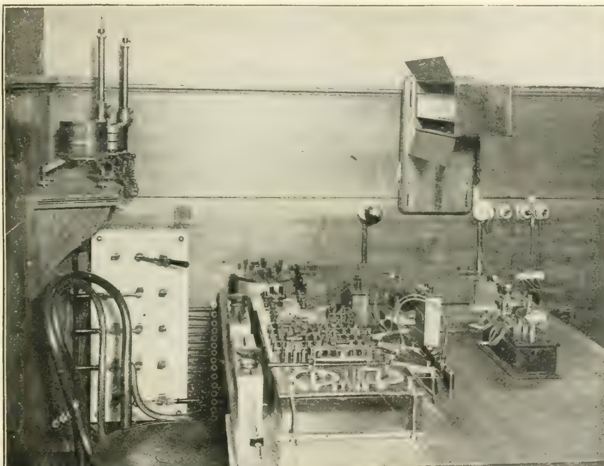

FIG. 2—VIEW SHOWING ARRANGEMENT OF GALVANOMETER, SCALE AND APPARATUS ON THE TABLE

The rheostat for regulating the current from the auxiliary cells to the potentiometer is provided with four plugs, two dials and a slide wire. The resistances connected across the plugs are 4 000, 3 000, 2 000, and 1 000 ohms respectively. The first dial has nine steps of 100 ohms each; the second, nine steps of ten ohms each and the slide wire has a resistance of thirteen ohms, giving a little extra

regulation. The dial and slide wire can be manipulated quickly and conveniently. Their contact resistances are very low, and have never given any trouble.

The rheostat for fine adjustment of shunt current consists of a ten ohm slide wire in multiple with a fixed resistance of about two ohms. In series with these is a plug resistance box for the rough adjustment in the plug current. With the slide wire at about mid-range the resistance in the plug box is set within 0.5 ohm of the right amount. On account of the shunt resistance of all meters being equal and the current being steady, very little adjustment is required

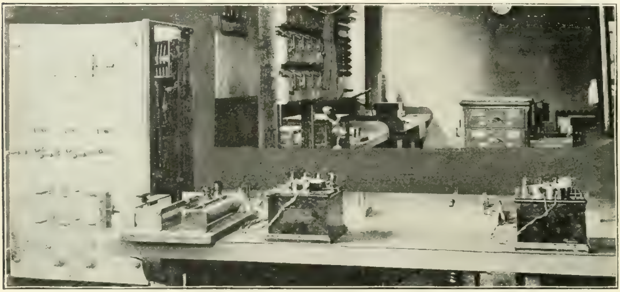

FIG. 3—VIEW OF TABLE WITH WATTMETERS UNDER TEST

and it is seldom necessary to reset the plugs. The table for the wattmeters under test and the controlling apparatus are shown in Fig. 3.

### DETAILS OF CALIBRATION

As an example of the application of this method, the calibration of a five ampere wattmeter will be described in detail. Its springs will have been tested at the factory to see that they were about the right strength, before they were put ino the meter. The zero reading may be correct but is not necessarily so. With no load on the meter, the position of the vernier on the deflection index when the fiducial index stands at zero is noted. The torsion head is then turned through one complete revolution so that the vernier is again in the position from which it started. Current is turned on both coils. The operator in charge of the standards adjusts the shunt current to 0.1 ampere while the one reading the wattmeter adjusts the series current. When the required reading of the wattmeter is

reached, the drop of voltage across the standard resistance in the series circuit is measured by means of the potentiometer. All currents are then reversed and the operation repeated. The potentiometer readings direct and reversed will be practically equal, as the reversal of current is merely to neutralize thermal voltages and any slight unbalancing of the astatically wound coils of the meter which might cause it to be influenced by a stray magnetic field.

Assuming that the temperature of the meter is 27.6 degrees, the two potentiometer readings, 0.50142 and 0.50146 volt, the resistance of standard in series circuit 0.10008 ohm, the average potentiometer reading, 0.50144, is used. From this must be subtracted 0.08 per cent owing to the discrepancy of that amount between Ohm's Law and the legal standards in this country. The e.m.f. of the cell used with the potentiometer is 1.0198 volt, based on the standard Clark cell. In terms of the standard ampere and ohm, however, it is only 1.0190. Consequently, in measuring the shunt current, which in practice will be proportional to the e.m.f of the circuit it is taken as $\frac{E}{R}$ in which $E$ is an e.m.f. in terms of the Clark cell, but the series current is equal to $\frac{E^1}{R}$, in which $E^1$ must be made to conform with the standard ampere and Ohm's Law, $R$ being on the same basis in all cases. If the series standard resistance were exactly 0.1 ohm the figures on the potentiometer could be read directly in amperes except for the cell correction. For convenience the standard resistances used in measuring current can be adjusted to 0.08 per cent below their normal ratings, thereby making the readings direct in amperes. In this case the resistance was 0.08 per cent high making the total deduction from the potentiometer readings 0.16 per cent. This correction will be constant as long as there is no permanent change in the standards. The temperature co-efficients of the cells and resistances are so low that the maximum error which could result from their variations of temperature would amount to something less than 0.01 per cent under the least favorable conditions. The working range of temperature is five degrees each way. Applying the correction to the reading and pointing off one place to reduce to amperes gives the current, 5.0064 amperes.

As the correction for temperature of springs is subject to slight variations all the time, due to variations in room temperature and warming of the coils by the current, there is no particular advantage in combining that correction with the others It has been found more convenient to correct the

wattmeter reading for the amount by which it differs from the reading which the same current would produce at 25 degrees. In the example under consideration the temperature was 2.6 degrees higher than 25 degrees and the temperature co-efficient of the springs was 0.04 per cent per degree. The reading was therefore 0.104 per cent higher than it would have been with the same current at 25 degrees. There are 250 divisions on the scale; the correction at full scale reading is 0.26 division or, at 25 degrees, the same current would have produced a reading of 249.74, which is the actual $D$ in the formula. With the 5.0064 amperes series current found by measurement, the constant, $K$, being 500, $D$ should be $500 \times 5.0064 \times 0.1$ or 250.32 at 25 degrees. Subtracting 249.74 from 250.32 gives 0.58 as the error in divisions. The meter reads 0.58 divisisons low at full-load. Therefore the springs must be weakened.

Changes in the strength of springs are made by means of a de-

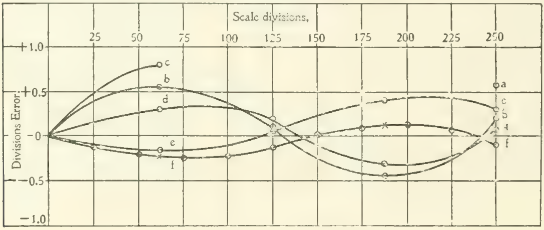


FIG. 4—CALIBRATION CURVES

vice similar to that used on the hair-springs of watches. It is not customary to take readings at lower parts of the scale until the full scale reading has been made nearly correct. Four readings, taken at one-fourth, one-half, three-fourths and full scale locate the calibration curve with a fair degree of definiteness.

In Fig. 4, $A$ is a preliminary point located as outlined above before the strength of springs was adjusted. $B$ is the curve after adjusting the strength but not making any other adjustment. All of the points from which the curves are plotted are located in the same manner as explained for full scale reading. $C$ is a point on a curve resulting from a trial adjustment to bring intermediate points into line without changing strength. This first adjustment of shape of curve is as likely to make it worse, as to improve it, for there is no means of knowing which way to make the adjustment except by trial. In this case the trial adjustment was evidently in the

wrong direction, as $C$ is farther removed from the axis than the corresponding point on curve $B$. To continue the curve would be useless. Having made one trial adjustment, it serves as a guide for further adjustments either by the same or reverse process according to whether the trial adjustment was beneficial or detrimental. $D$ is the result of an adjustment opposite to that which produced $C$. $E$ is a further development along the same lines as $D$ but a little overdone. In this instance the full-scale reading was affected. The shape of curve $E$ indicates that a strengthening of springs which would make the full-scale reading approximately correct would also bring all of the lower points close to the axis without other adjustment. This was done, and the resulting curve is $F$. It is interesting to note that $F$ follows the same characteristic shape as $E$, but is about 0.15 per cent lower throughout. In locating it, readings were first taken at points marked $X$. These points being within 0.25 division of the axis which is considered a reasonable allowance for the maximum departure of curve, readings were taken at ten other points equally spaced throughout the scale and the final calibration curve was drawn through them.

The reason for taking such a large number of readings is to eliminate any error of observation or personal error on the part of either operator. It is scarcely conceivable that errors of this class could enter into the location of two or more consecutive points without becoming apparent through the irregularities they would introduce into the shape of the curve. If the springs are properly made and mounted so that none of their convolutions come in contact with each other, nor with a fixed part in any position, the relation between torque and deflection can not vary spasmodically, but must change from one value to another in a uniform manner. The calibration curve must pass through every point obtained from the readings. If any point is so located that the curve cannot pass through it without making a sharp bend it is evident that there is something wrong and the cause of the trouble must be found.

The only errors that can escape detection in this way are such as are constant or varying uniformly throughout a test. This limits them to errors in standards and effects of steadily increasing or decreasing temperature due to corresponding slow changes of load. Errors of the former class are minimized by using standards which are not subject to variations, and testing them frequently. The latter condition is avoided by using apparatus with low operating temperature and low temperature co-efficient.

When described in detail, the various steps in calculating the location of points on curves after the readings have been taken seem laborious. Calculations are facilitated by the use of tables and curves prepared for the purpose, but the corrections of common occurrence soon become fixed in the memory so that it is not necessary to calculate them each time, nor even to refer to a table.

### POWER SUPPLY

Both shunt and series currents come from storage batteries. The e.m.f. applied to the shunt circuit is usually twenty volts when only one meter is in circuit. Higher voltages can be applied to suit the number of meters. The e.m.f. applied to the series circuit is always ten volts. Grid resistances are used for the approximate adjustment of current; closer regulation is obtained by means of slide wire resistances. At ten volts the regulation is good but it would not be economical to attempt to work at a much lower voltage. For convenience, and therefore quickness, the greater part of the resistance in circuit must be in the regulating resistance. If the resistance of the instruments and connections and the internal resistance of the battery are a large part of the total resistance in circuit at full-load, a certain change in the regulating resistance does not produce anything like the same effect in amperes that it would produce at lower loads. This is easily demonstrated by assuming any constant resistance and adding variable amounts to it. If it is necessary to reduce the adjusting resistance almost to a short-circuit to give the maximum current required the resistances inserted for other values of current will be inconveniently irregular.

### MODIFIED FORMS OF METHOD

The amount of apparatus required in calibrating a wattmeter by this method can be reduced by shunting the series potentiometer with a resistance such that the current from the auxiliary cells to balance the standard cell will be 0.1 ampere. The shunt winding of the wattmeter can then be connected in the potentiometer circuit and the current in it will always be correct when the standard cell is balanced for reading series current. In this way the shunt potentiometer with its standard cell, galvanometer, lamp and scale and also the rheostat for series potentiometer can be dispensed with. The operator has only one rheostat to adjust and one galvanometer to watch. This plan has been tried on another potentiometer which is designed for 1.5 volts and has a resistance of 15 200 ohms. A

shunt for it was adjusted to 15.215 ohms, which is the resistance required to give a balance with a standard cell and make the instrument direct reading in volts when the total auxiliary current is 0.1 ampere. The advantages of this connection are more than offset by its disadvantages. Both batteries must be comparatively large. The perfect insulation between auxiliary and working batteries essential to potentiometer measurements is difficult to maintain. Furthermore, with two such batteries connected together through the potentiometer coils, the coils are in constant danger of being burned out if the battery circuits were accidentally connected at some other point.

To calibrate wattmeters having odd shunt resistances it would be more convenient to measure the shunt voltage than the shunt current. The general method would not necessarily be different. The standard in the shunt circuit would be of high resistance with a tap at the right point for the standard cell connections and would be connected in multiple with the shunt of the meter instead of in series with it.

Instruments which are influenced by the earth's field can be more accurately calibrated by measuring the current in direct and reversed relations while the coils are in the same position in both instances than by averaging the direct and reversed readings with the same current. When the readings are not alike in both measurements the effect of the earth's field is different, depending upon the distance apart of the readings, except in zero-reading instruments.

Rheostats for the fine adjustment of series current are provided on both tables. When desirable the current can be adjusted to give even readings on the potentiometer while the readings of the wattmeter are observed. This plan has the advantage that several observers can take readings on a number of wattmeters while only one is occupied with the standards.

### ACCURACY

The accuracy with which readings can be duplicated may be stated as a constant amount for all parts of the scale. All calculations are carried to hundredths of divisions. It is quite common to duplicate readings at different times exactly. It is probably more common to come within 0.02 division of the same reading; while 0.03 division is considered a fairly good check. There is seldom any difficulty in checking a reading within 0.03 division. A dis-

crepancy of 0.03 division amounts to 0.03 per cent at four-tenths of full scale reading and 0.015 per cent at eight-tenths of full scale reading.

Crooked curves repeat themselves as accurately as flat ones. The springs are adjusted to give as flat a curve as possible so that for most purposes the correction curve can be entirely ignored. If all readings were to be corrected in accordance with the curve, there would be no advantage in reducing the correction to a minimum as the large corrections usually found in the original trial curves are quite as definite as the small ones remaining in the final results.

The calibration of a wattmeter is not complete until it has been tested to see that it has no defects which would lead to error when it is used with alternating current. These tests are, of course, made with alternating current and are merely in the nature of a check on the mechanical condition of the instrument. Alternating currents are seldom steady enough to be comparable with storage battery current. The probable error of observation is therefore higher in the practical use of the meter than in the laboratory where it was calibrated. In adopting this method, it was not expected that a considerable number of instruments so calibrated would, in service, be read to hundredths of divisions, but it was intended to calibrate them with such precision that the only practical limit of accuracy in service would be the limit to which errors of observation could be reduced.

# NOTES ON RHEOSTAT DESIGN

F. D. HALLOCK

IN THE design of rheostats, especially where a complete line for various purposes is to be laid out, there are a number of points of interest. Some of these points are considered under the following headings:

1. Classes of rheostats.
2. Types of rheostats.
3. Resistance material.
4. Resistance units.
5. Manufacturing facilities.

Rheostats may be divided into two classes,—those employed in the main or series circuit and those employed in the shunt circuit. Of these the first class may be again divided into intermittent service rheostats and continuous service rheostats, while the second class is ordinarily used for continuous service. All rheostats will come in these two classes and sub-divisions.

### SERIES CIRCUIT—INTERMITTENT SERVICE

*Motor Starting*—Where rheostats are used for this purpose particular attention must be given to the conditions of starting. For instance, they may be used occasionally for starting with the motor under full-load; for starting under no-load, after which the apparatus is cut out of circuit; for starting machine tools, railway cars and various other apparatus.

### SERIES CIRCUIT—CONTINUOUS SERVICE

*Regulating*—Rheostats of this class carry the main current and are subject to hard service. Some examples of their use are: On cranes, ventilating fans, some types of printing press controllers, elevators, organ regulators and battery charging outfits.

### SHUNT CIRCUIT—CONTINUOUS SERVICE

*Field Regulators*—Rheostats of this type are used to govern the field current of generators and motors and sometimes in shunt with the series fields of large machines.

The foregoing comprise the main classes of rheostats as far as electrical considerations are concerned. There are many variations and combinations of these, including auxiliary, automatic and non-

automatic attachments for performing certain functions, but the consideration and preparation of data for the electrical design of these named fully covers the subject.

### TYPES OF RHEOSTAT.

The type of rheostat is an important consideration. There are two distinct types on the market, the open type and the embedded or enclosed type. In the former the resistance material is open to the air, capable of easy inspection and repair and at the same time protected from injury; in the latter, as the name indicates, the material is embedded in some substance, such as enamel, sand or cement. Unless the units are small these are difficult to repair or expensive to replace and in certain designs are subject to grounds through absorption of moisture. Each of these different types has its merits, but where rheostats are to be made for all the needs of the purchasers the open type with suitable composite units seems to be the most acceptable to the manufacturer and the consumer alike, except where extreme conditions of a special nature are to be met and the resistance material must be entirely enclosed. This small percentage of cases can be taken care of by enclosing the open type and yet not depart widely from standard design nor at all from standard units.

### RESISTANCE MATERIALS

Resistance materials must be selected according to the type of rheostat; for instance, in an open type starting rheostat, a galvanized iron wire can be used with perfectly satisfactory results, while the same wire could not be used in the embedded type. In fact the latter calls for a material with practically no temperature coefficient. This generally means an alloy and hence an unnecessarily expensive material.

For starting rheostats a resistance material with a considerable positive temperature coefficient is not a disadvantage, but rather an advantage, in that its increased temperature under constant service raises its resistance, thus lowering the current and protecting itself and also the apparatus it controls in case of attempts to misuse it. For continuous service a resistance material having practically no temperature coefficient is desirable. In field rheostats or rheostats for definite speed adjustment or voltage regulation, the operator does not care to make an adjustment with each change of temperature. Materials having a negative temperature coefficient are generally to be avoided unless there is some special case where an automatic decrease

in resistance is desirable, but such a decrease is better arrived at by the use of other attachments or automatic features.

There are numerous new resistance materials appearing from time to time, but it must not be accepted that any resistance material which has the resistance is applicable to the case in hand. Its composition in view of its proposed use should be very carefully considered as certain of its ingredients under given conditions may cause it to fail. Other material may be well suited as a resistance yet not sufficiently strong mechanically to be of economical use.

RESISTANCE UNITS

Resistance units capable of being easily assembled are preferable. The sizes of these units should be determined by mechanical as well as electrical considerations and it will be found that a small number of units may be used for a large number of rheostats. Suppose, for instance, two units are selected to be wound with wire and three units to be of cast resistance material, say iron. The wire wound units can be wound with any size of wire from 0.0808 in. to 0.003 in. diameter. The limit of capacity of such a type, is soon reached, however, and either units must be paralleled or some units of higher capacity found. The former method of obtaining the capacity is too expensive to be considered from a manufacturing standpoint and too inconvenient from the repairer's standpoint. For large capacity the cast iron grid, a well known and universally approved type, can be employed. By varying the cross-section and length of convolutions suitable variations in ohmic resistance can be obtained, and by keeping the supports common to all, the units are capable of easy assembly and renewal.

*Starting Rheostats*—For starting service it may be assumed that the process of starting covers so short a time that the entire energy absorbed in the resistance material and transformed into heat has not time to be radiated or

$$\text{Heat Generated} = \text{Heat Absorbed.} \quad (1)$$

One heat unit = 1 055 joules or watt-seconds.

*A*—Area of cross-section of material, in sq. in.

*C*—Maximum allowable amperes before reaching the temperature limit.

*R*—Resistance of one cu. in. of material in ohms.

*t*—Allowable time to reach maximum temperature.

*W*—Weight in lbs. of one cu. in. of material.

*H*—Specific heat of material.

*T*—Maximum temperature allowable in degrees F.

*L*—Length in inches.

from (1)

$$C^2 R \times \frac{L}{A} \; t = A\,L\,W\,H\,T \times 1055$$

$$\text{or, } C = A \sqrt{\frac{1055\ W\,H\,T}{Rt}}$$

With the above relations as a basis capacity curves for different units can be laid off as shown in Fig. 1, and these curves used in selecting the proper units to use for any given starting service.

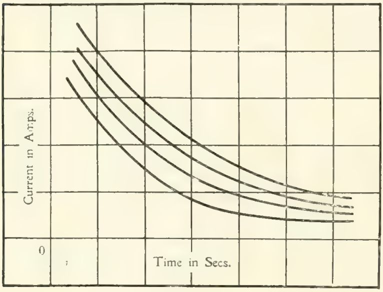

FIG. 1

Next the number of steps it is necessary to use in starting may be determined. In practice this number is found to range from three to ten steps. On starting rheostats there are commonly from four steps on small work to seven or ten on large sizes. Where machines can come up to speed quickly without load a small number of steps is sufficient, especially if the apparatus is handled by an experienced operator. As an example, large generators and rotary converters are often started on three or four steps. Where motors take considerable current to start it is best to have several steps, especially if the supply circuit is also used for lighting.

A curve of acceleration for a motor armature is shown at *A* in Fig. 2. This curve also represents the rise of counter e.m.f. of the motor, the absence or presence of which makes more or less resistance necessary. For convenience the horizontal line is divided into equal steps and the vertical line into percentages (100 per cent total). In this way the proper percentage at each step or per step that should be inserted in the armature circuit can be determined. With the rheostate on the first step and a predetermined armature cur-

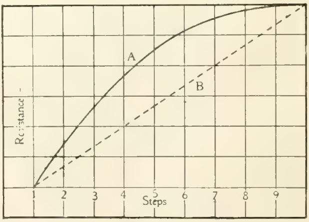

FIG. 2

rent, $C$, the total drop is, $C\ R$. As the armature has not started this must all be taken up in the resistance.

Thus, $C\ R =$ e. m. f. of line

and $R = \dfrac{\text{e. m. f. of line}}{C}$

which is the proper resistance to have in series when the circuit is first closed. The motor should start while on this notch. Then

$C\ R^1 =$ e. m. f. of line—c. e. m. f. of motor.

or $R^1 = \dfrac{\text{e. m. f. of line—c. e. m. f. of motor}}{C}$

Then $R—R^1$ equals the resistance that should be between the first and second steps. In a similar manner the resistances of the other steps may be determined.

By dividing the number of steps into the total time for starting—from fifteen seconds for small motors to forty-five seconds for large machines—the necessary time each step should be in circuit may be determined.

The steps should be so proportioned that the fluctuations in current will be uniform when the rheostat arm is moved from step to step in equal time intervals as shown in Fig. 3. This figure also indicates that the greater number of steps the less the fluctuation in current. The form of curve, *A*, in Fig. 2, governs the uniformity of fluctuations. If a straight line curve, as at *B*, was followed and as much resistance cut on the last step as on the first, the fluctuations would be much greater at the last steps.

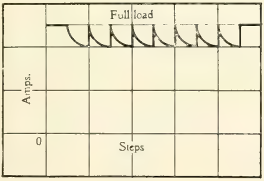


FIG. 3

The standard lines of starting rheostats are designed for a certain load. While some variation is allowable, the rheostat which is too large for the motor it is to start will have too little resistance and subject the motor to too much current. Likewise, the rheostat which is too small will not allow sufficient current to pass until several steps have been passed, and the motor thus has only two or three steps remaining to start it. The motor of comparatively large number of steps is capable of better performances on a wide range than one of a few steps, for the reason that in the latter case if the motor does not start on the first step, and the rheostat must be moved to the second or third step, it has very little resistance remaining and the motor

will start with a jerk and may injure itself or some other apparatus which it controls. Therefore, a rheostat of a few steps is only safe when applied to the particular service and motor for which it was designed. Thus a motor intended to employ considerable time in starting or starting with a much greater load than that for which standard starting rheostats are designed should receive special attention in order to get good results.

*Continuous Service Rheostats*—Advantage of radiation may be taken when rheostats are for continuous service. Under the application of current the temperature of the wire will continue to rise until the heat radiated equals the heat generated, when a steady temperature will be reached. If the energy received is greater than the material can radiate without reaching a temperature that will endanger the material or exceed prescribed limits, this energy must be decreased. As energy converted into heat equals the current squared times the resistance in ohms, or watts, and, as in a given unit the ohms cannot well be reduced, the current must be reduced. The same size of unit, however, may be wound for a different resistance which gives a corresponding change in current carrying capacity. Therefore, it is best to speak of the capacity of any given unit in watts equals $C^2R$, since $C^2R$ equals a constant for the same thermal conditions and unit. No matter, then, what piece of apparatus is under consideration it is dissipating a certain number of watts per square inch of surface when the rise in temperature is a certain number of degrees above the surrounding air and it cannot get rid of any more heat until the difference of temperature is increased unless artificial means, such as a blower or some other means of carrying away the extra heat is used. No matter what the material or its form, the ultimate temperature is will stand without failure can be estimated if its capacity in watts is known. If the current carrying material is exposed to the air, or if it is surrounded by or packed into another material which is a good radiator of heat, its temperature can be figured and reduced to watts per square inch of surface at the place where the heat must be dissipated and the safe rise so determined.

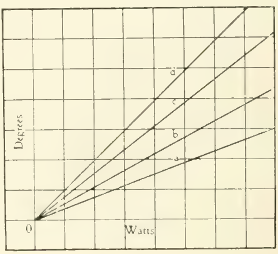


FIG. 4

Curves of standard units may be plotted, as in Fig. 4, which will show the temperature rise when using up a certain number of watts

under certain conditions, i. e., the resistance may be exposed to the air or enclosed in a box or subjected to any standard or special predetermined conditions. The safe maximum temperature for the material having been ascertained, any specification as to rise in temperature can be met and the limiting number of watts allowable for the respective units determined.

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In the design of field rheostats tapered resistances can be used, i. e., the first step has higher capacity in amperes than the next one, and so on. In this way the resistance of the units may be increased with the steps as long as the watt capacity of the unit is not exceeded. In laying out a tapered resistance for a low voltage line, it will be seen that the next higher resistance unit can be inserted without exceeding its capacity sooner than on a high voltage line. This explains why a field resistance for a 500 or 220 volt motor can be used on 110 volt service as long as its first step capacity is not exceeded, while a 110 or 220 volt rheostat cannot be used under the same conditions on a 500 volt line without danger of a burn-out. Sufficient resistance is usually supplied in a field rheostat to reduce the field current to three-fourths of its no-load value.

When field rheostats are to be designed for variable speed motors it is only necessary to find the maximum and minimum field currents and the shunt field resistance. The former are taken from the speed test curve. The line voltage divided by the maximum speed current less the field resistance, is the required amount of resistance in the rheostat. The hot and cold resistance of the shunt field varies about twenty per cent and the results are affected accordingly.

The design of rheostats for speed variation by resistance is governed by the armature speeds, these speeds being proportional to the voltage on the armature. For instance, if half-voltage speed is desired at the first step, the current at this speed must be determined and half the line voltage used up in resistance, or,

$$C\,R = \tfrac{1}{2} \text{ line e. m. f.}$$

The proper units can then be selected having the required

resistance and capacity. The other steps may be determined in a similar manner.

*Contacts and Parts*—The design of contacts and parts is the same as for other standard electrical work. Parts must be heavy enough to carry the maximum current without excessive heating. Twenty degrees C. rise above the surrounding air is a good maximum, and as a rule should not be exceeded for contacts and face parts. Many automatic and non-automatic attachments and safety devices, some required by the Underwriters and some by specifications of customers, are necessary to the performance of the apparatus and are mounted on the rheostat face plates, but they are not a part of the rheostat design proper.

### MANUFACTURING FACILITIES

Manufacturing facilities must be kept constantly in mind by the designer. If the plant is small there may be tools suitable only for performing certain operations economically and the more complicated and costly operations must be avoided. The quantity that can be produced must also have a bearing on the design, determining whether to use castings or punchings or screw machine-made parts or hand-turned parts. There are many places where it will be advisable to determine whether it will be of advantage to use a piece of outside manufacture or make it in the shop. Where there are specialists in this line it is usually best to take advantage of the fact on the principle that it is hard to beat a man at his own game.

The Underwriters' rules must be followed in designing all electrical apparatus and a knowledge of the relative merits and costs of different insulating materials is indispensable.

# A NEW FORM OF INDUCTION AMMETER OR VOLTMETER

PAUL MacGAHAN

DESCRIPTIONS of the older forms of induction ammeters and voltmeters, and of the Schuckert meter have appeared from time to time. In these designs, compensating windings, or "correcting coils" have been resorted to, in order to reduce the effects of frequency, wave form and temperature changes, but no description has yet appeared of the interesting method by which the induction principle, applied to the modern Westinghouse alternating-current type meters, has been made to produce the desired result. This method was due originally in principle to Mr. Frank Conrad. The meters are naturally independent of the quantities which detract from the accuracy of practically all other commercial alternating-current meters except the hot-wire type, whose mechanical drawbacks and self-heating errors are still more objectionable.

As is well known, the torque of induction meters is an effect identical with that of induction motors; the meter being a miniature motor whose rotor is a light disc or shell usually made of aluminum, and whose field is energized by the current to be measured. As in the induction motor, a rotary magnetic field is required to produce torque, which is obtained by producing two fields out of phase with each other.

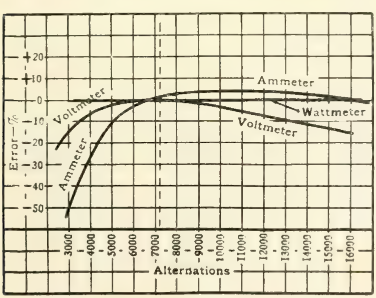


FIG. I—CURVE OF FREQUENCY ERRORS

In the simplest form of induction meter, the rotary field is produced by a "split phase" winding. Where no corrective devices are employed, the torque is proportional to: 1, the square of the total current; 2, the first power of the frequency; 3, the characteristic losses in the iron, and 4, the reciprocal of the rotor resistance. As the rotor resistance is practically proportional to the absolute temperature, the torque depends upon the temperature coefficient of the rotor.

Assuming the frequency in a commercial plant to vary 10 per cent and the temperature to vary 20 degrees C., the simple induction ammeter would have a maximum frequency error of 10 per cent and a maximum temperature error of 8 per cent and, therefore, could not be counted on to be more accurate than 18 per cent, no matter how cerefully it might have been constructed and calibrated.

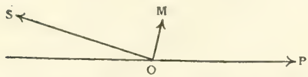


FIG. 2—SERIES TRANSFORMER VECTOR DIAGRAM

In the original induction ammeters compensating coils were used, wound non-inductively with copper, and connected in parallel with the magnetic coils. As the frequency increased, the compensating coils took more of the current, and as the temperature rose, they took less; thus compensating, in quite a satisfactory manner for the errors due to frequency and temperature. The frequency errors are shown by the curve in Fig. 1. The temperature coefficient was reduced to 0.08 per cent per degree C., or one-fifth of that in the "simple induction meter." However, this was at the expense of efficiency and torque, and the windings were necessarily complicated. The same objections hold true of the European makes of induction meters, in even a greater degree.

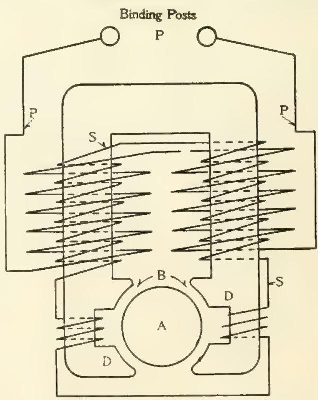


FIG. 3

To obtain a system inherently correct, it is obviously necessary to make the induction vary inversely as the frequency, and directly as the temperature. Such a circuit can be produced in a simple, automatic manner, without any corrective devices by means of the series transformer with a non-inductive, copper resistance secondary. Assuming the current in the primary to be constant, the secondary current will be approximately constant; the more perfect the transformer, the more nearly constant; thus the frequency increases, the induction will decrease in direct proportion. Also as the temperature, and consequently the resistance of the secondary coil increases, the in-

duced voltage and consequently the induction, increases proportionally. If, therefore, the magnetism of the series transformer could be made to drive the rotor of the induction meter, the meter would be theoretically independent of the frequency and emperature within wide limits.

In the simple vector diagram of a series transformer, Fig. 2, let *OP* represent the product of the primary current and primary turns, and let *OS* represent the product of the secondary current and secondary turns when the resistance of the secondary is entirely ohmic. Then ,neglecting the losses, *OP* will equal *OS*, and will be very nearly 180 degrees out of phase, the angle *S O P* depending upon *OM* which represents the magnetizing current required. The induction produced will be in phase with *OM*. The current *OS*, instead of passing through a non-inductive secondary winding can be made in turn to magnetize a portion of the magnetic circuit, in which case the magnetism it produces will be in phase with this secondary current or in the direction *OS*. The more near perfect the device, considered as a series transformer, the more nearly will the two fluxes *OM* and *OS* be at right angles. In order to have a perfect rotary field, it is only necessary to properly place the coils *OP* and *OS* within reference to each other.

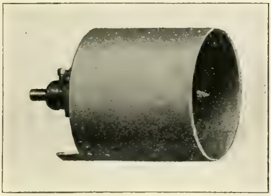

FIG. 4—METER MOVEMENT


FIG. 5—SWITCHBOARD TYPE AMMETER

The series transformer principle can be made to serve the double purpose of producing a rotating field without using a "phase splitter" and of producing a field which, in conjunction with a proper rotor, will produce a torque independent of the frequency and of the temperature, within wide variations. It is found that by keeping the induction and losses very low, variations in wave form produce no appreciable effect whatever upon the torque.

These principles, when properly applied, mechanically, to a me-

ter, produce a device which is ideal, and far superior to any other form of commercial meter, either alternating or direct. The contention that commercial alternating-current meters are, inherently, not as accurate as direct-current meters no longer holds. The freedom from external field effects, the lack of moving wires or iron, the light simple movement and the scale subtending an arc of 300 degrees are advantages over the best forms of direct-current meters which cannot be gainsaid.

As actually worked out, there is an electromagnet as shown at *A* in Fig. 3 in which *A* is the laminated magnetic field with an air gap *B*, in which a very light aluminum drum rotates. This drum shown in Fig. 4 weighs only 3.73 grammes, yet produces a torque of 2 cm. grammes at full load. The complete movement, including spring and pointer, weighs only 6 grammes. The drum is mounted on a shaft, to which also are attached, in the usual manner, the controlling spring and a pointer traveling over a scale. Jewel bearings are provided. A simpler or more rugged movement could not easily be devised.

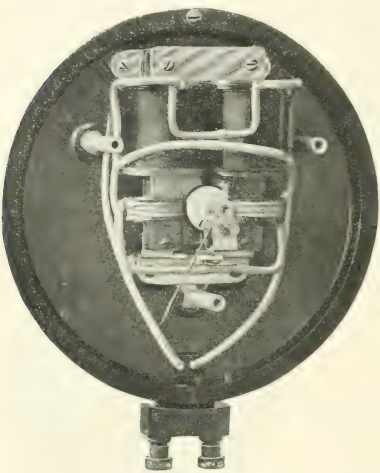

FIG. 6—VIEW SHOWING DETAILS OF METER MECHANISM

The primary winding is shown in Fig. 3 by lines *P*, the secondary by lines *S*. To vary the capacity of the meter, the number of primary turns and size of wire, only, need be changed. In voltmeters, many turns of fine wire are used in the primary, in conjunction with a separate high resistance wire of zero temperature co-efficient. The secondary coil is wound directly under the primary and connected to the auxiliary coils on the pole pieces, *D-D*. These poles thus form in effect a two-phase bi-polar rotary field. The induction is sufficiently high to make the damping effect cause the in-

dications to be "dead beat" without the use of additional damping magnets.

Fig. 5 shows the completed meter for use on a switchboard. Fig. 6 shows the same type of meter with cover and dial re-

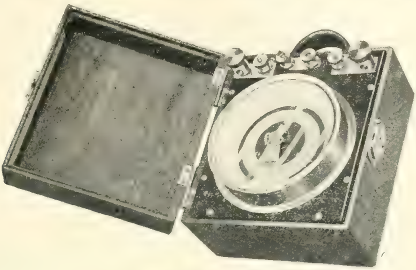

FIG. 7—PORTABLE TYPE METER

moved to show the movement. Fig. 7 shows the same principle applied to portable meters. It is also applied to edgewise and to illuminated dial meters with equal success. The frequency error in these ammeters is practically negligible between 2 000 and 8 000 alternations, as shown in Fig. 8 and the temperature co-efficient varies

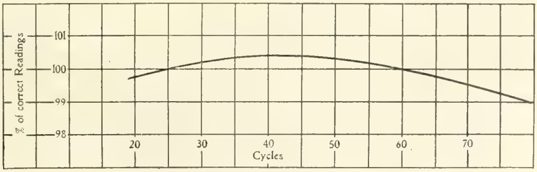


FIG. 8—CURVE OF FREQUENCY ERROR

in individual meters from plus 0.01 per cent to minus 0.01 per cent. The voltmeters are only slightly inferior in frequency error to the ammeters, and quite as good as regards temperature. The meters take eight watts, at normal load, to operate them.

# A SELF-REGULATING BRAKE

H. M. SCHEIBE

THE inconvenience and uncertainty involved in hand regulation of the common prony brake has led to the development of a simple automatic device that is well adapted to motor loading and especially for motors of small power.

The scheme of loading is a familiar one and is shown diagrammatically in Fig. 1. The equal weights $W_1$ and $W_2$ supply the tension that makes the strap grip the pulley and the torque thus developed is balanced by the weight $W_3$. The automatic feature of the device consists in the special construction of the strap used. It may be made of any flexible material with a good friction surface, but from its center to one end it should be provided with a flexible metallic surface on the side that is to face the pulley. Such a strap may be readily made from a piece of leather belting studded with copper rivets as indicated in Fig. 2. For accuracy at light loads the belt must be quite flexible. The operation of the device is apparent from the sketch. $W_3$ is placed on the end of the strap provided with the metal surface and hung from the rising side of the brake pulley. If the torque developed overbalances $W_3$ this weight will rise and the strap shift on the pulley, until more copper and less leather are in contact with the pulley rim. This lowers the average coefficient of friction to a point that will just balance $W_3$ so that the amount of this weight determines the torque to which the brake will adjust itself. The difference in the friction coefficients of leather and copper is so large that a wide range of torque may be obtained without changing $W_1$ and $W_2$.

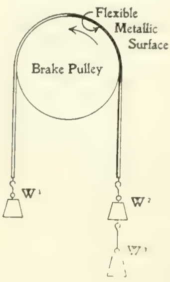


FIG. 1

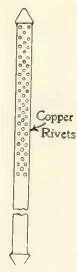


FIG. 2

For example, in one test with a one-inch strap on a four-inch pulley, with $W_1$ and $W_2$ each one-half pound weights, it was found that on changing $W_3$ from one-half to five pounds, the belt moved only about two and one-half inches. This was a ratio of one to ten which is amply wide for ordinary purposes, as the usual range in

shop testing of motors is from one-fourth to one and one-half full-load, or one to six. In the case cited the brake could have handled almost twice the maximum load given had not the motor "pulled out." By changing $W_1$ and $W_2$ the range can be extended still further, thus giving the brake a very flexible capacity.

The automatic feature of this device takes care of all changes in the friction surface due to variable temperature and other causes. This fact was quite effectively demonstrated in a test on an experimental brake in which oil was applied to the brake pulley while running. The oil simply caused the belt to shift to a new position where it continued to operate as before.

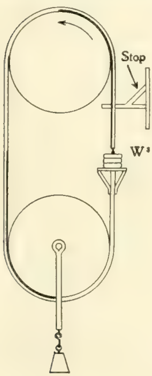


FIG. 3

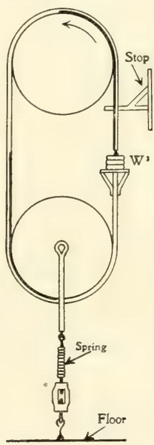


FIG. 4

For very accurate work on small motors it may be worth while to balance the strap by making it a continuous belt with two "rivet patches" so placed as to balance each other. In this case the weights $W_1$ and $W_2$ may be replaced by a light pulley carried in the lower loops of the belt and the desired tension obtained by a single weight or by a spring or other mechanical take up as shown in Figs. 3 and 4.

In ordinary work, however, the simpler scheme first described will be sufficient.

In figuring results it must be remembered that the brake arm is not the radius of the brake pulley, but exceeds this by one-half the thickness of the belt.

# EXPERIENCE ON THE ROAD

## "THE TROUBLE MAN"

S. L. SINCLAIR

A MAGICIAN was engaged to entertain those in attendance at a smoker recently given by a certain organization, and, while he performed, the writer heard a gentleman remark, "He would make a good man on type ——," referring to some apparatus, the troubles with which had been rather annoying. The gentleman who made the remark is in charge of a department which might properly be known as the "Department of Correction." The reason for the remark was the difficulty experienced by him in securing men capable of locating and remedying troubles and the inference was that men of this type need the ability of a magician. For this reason the man who can fill the position of a "trouble man" effectively is a man much sought for. The ability to locate faults and remedy them requires brains, and perseverance to an almost limitless degree. The successful "trouble man" should be a mechanic, an electrician, theoretically and practically, should have tact and should not hesitate to take off his coat, roll up his sleeves and go to work. The difficulty with most men is that they reach conclusions too hurriedly and thus frequently cause very serious loss to the user of the apparatus and embarrassment to their employer.

The writer has in mind an instance where a man was detailed to locate the trouble in an induction motor which would not operate continuously up to speed. He reached the conclusion that the starting device was burned out and that a new resistance was necessary. This decision caused the shutdown of the shop in which the motor was used. At the end of several days the owner telephoned that he could not wait longer and that something must be done to get his shop in operation. The resistance was returned and repaired by another man who found that the trouble was due to a loose connection in the secondary winding. This was repaired and the motor placed in service, using the old starter.

The above is only an example of many such occurrences which cause no end of trouble and expense to the user and to the manufacturer of the apparatus.

THE

# ELECTRIC JOURNAL

VOL. IV. MARCH, 1907 NO. 3.

**Electro-Pneumatic Railway Apparatus**

The extent to which electricity is augmenting and assisting the application of compressed air in manipulating apparatus in connection with railway work is not generally understood. The articles in the JOURNAL by Mr. W. H. Cadwallader describe its application to railway signaling, in which field it plays a very important part. In the operation of an extended system of mechanism, like a set of interlocked signals and track switches, there are of necessity a great many movements of parts. A number of these movements require but little effort. The movement of the important functions must be so interconnected that they will follow each other in a certain predetermined order. It is this interconnecting that is the easy part and requires but little work, but is all-important.

In the development of the system described, compressed air is used to do practically all the work performed, electricity serving to interconnect the movement of the principal functions. The natural question arising in this connection is, "If electricity is to be introduced into the system, why not use it to do all the work and perform all the functions?" Here again it is 'the survival of the fittest." Owing to the intermittent character of the work, the mechanism necessary for the application of compressed air to the work is very much simpler than that required in the application of electricity to the work. However, it is the combination of the two that works out the simplest and most direct application, the electric part serving as the nerves of the system, the compressed air as the muscles controlled by these nerves.

The use of electricity for this part of the work has two very important advantages over any mechanical means—that of speed and reliability. The first statement, of course, needs no argument to demonstrate its truth, and the second is equally true for the reason that the question of wear of parts is practically eliminated. If an indicator shows that a certain circuit is closed it is pretty sure to be closed, although that is, of course, not absolute proof that the device that was to operate to close the circuit has operated. However, as

electric circuits themselves do not wear and the contact makers that are intended to close the circuits tend to wear open rather than closed, the system can be depended upon not to lie. This condition is still further safeguarded in systems of electro-pneumatics, as described in the articles referred to, by using an electric circuit of low voltage, the tendency of the current to close its own circuit being thereby very much reduced.

Another application of electro-pneumatics to railway work on about the same lines is that of the electro-pneumatic train control of electric cars or locomotives. In this system any number of motor cars or locomotives can be coupled into a train and controlled from one point by a single operator. In this system the electric circuits passing through the train are used to actuate magnet valves very similar to those used in connection wih signalling apparatus, these magnet valves controlling the admission and release of air to cylinders which are directly connected to switches that manipulate the electric circuits of the motors on the different cars of locomotives. In this system each car or locomotive supplies its proportionate share of the motive power, as well as its proportionate share of the braking power on the train. It also supplies its proportionate share of the small amount of electric energy required to supply the control circuits. In other words, each car or locomotive is an absolutely independent unit. However, by this system of control each unit must perform its proportionate share of the work simultaneously and in harmony with all the other units. The operation of these units is positive, both in the application of the power and the brakes, for the reason that by the use of compressed air ample power is at once available for the prompt manipulation of the controlling and braking apparatus. Also the application of the brakes and the removal of the power are so electrically interlocked that, if the operator removes his hand from the master controller, power will automatically be cut off and the brakes applied. By this system a train of motor cars comprising a total of perhaps four or five thousand horsepower are absolutely and safely controlled in all their movements by a small controller manipulating low voltage electric circuit of but a few watts total energy.

From this brief description of the train control system and from the description of the signaling systems, it is evident that electro-pneumatics cover quite a wide field in railway operation, especially in electric railway operation.

William Cooper

**Loyalty and Responsibility**

Loyalty and responsibility cannot be too greatly emphasized and the contribution in this issue upon this subject goes far toward pointing out the shortcomings of many of us. Some may consider, perhaps, that the issue involved is not coincident with the objects of the JOURNAL. But, are we not liable to overlook the question in the great rush of business in which we must ultimately fail unless we keep before us the importance of these two great factors, "Loyalty and Responsibility," which are essential to success in any undertaking.

A recent sermon by Dr. Parkhurst presented this subject in a most direct and forceful manner. After the editor of the JOURNAL had accepted my suggestion that an article of this kind would be suitable, I presented the situation to Dr. Parkhurst and the result is the article in this issue, based upon his sermon delivered in the Madison Square Presbyterian church, in New York City, on December 30.

S. L. SINCLAIR

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**Electric Motor vs Steam Locomotives**

Over one million dollars a day is the cost of steam locomotives in the United States. These figures include fuel—nearly half a million dollars a day—engine and round house men, repairs and renewals. This cost may be reduced considerably more than one-half by the substitution of electricity. Such is the estimate which is the basis of the paper on the "Substitution of of the Electric Motor for the Steam Locomotive," by Messrs. Stillwell and Putnam, before the American Institute of Electrical Engineers. Whatever be the saving were all roads to be electrified, the gain will obviously show a much higher percentage for the ten percent or twenty-five percent of the railroads on which the conditions are most advantageous. The extent of this field of electrical operation is almost appalling. The initial electrical equipment of locomotives and power houses would approximate $600 000 000, which is about equal to the value of six years' output of the General Electric and Westinghouse companies. The copper conductors which the paper specifies would require the total copper production of the United States for the past five or six years.

The transcendent importance of standardizing equipment is one of the leading features of the paper. Discussion brings out the fear least standardizing may limit progress. Granted that many

features cannot be fixed at present, still there are others in which variations are seemingly not justified. The fact that the third rail conductors of different roads in New York City occupy four different positions, is an example of the lack of standardization. It is well, of course, that final standards were not fixed some five years ago, when the single-phase motor was regarded as a sort of unattainable ideal, else nearly all of those who discussed the Stillwell-Putnam paper would be heretics. Of the dozen gentlemen who spoke only one, the honored "father of the electric railway," proved loyal to the direct-current motor, while one other had a good word for the three-phase motor. Otherwise the single-phase motor had the field.

The discussion did not ask, "What system shall we use?" nor "Is the single-phase self-starting, non-sparking motor a real thing?" nor "Should the single-phase motor be of the straight series or of some other type?"—for these things one can refer to recent volumes of institute transactions—but "Should twenty-five cycles per second or fifteen cycles be adopted in railway operation?" It may be noted that Mr. Lamme's original paper describing the single-phase system answered all these queries, and the discussion has now come to the question of frequency. He recommended a low frequency then, and he does now.

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**Choice of Frequency**

Choice often must be made between sixty cycles and twenty-five cycles for general purposes. In many cases there is little difference in so far as generator speeds, transmission losses, motors, and incandescent lighting are concerned. A change to fifteen cycles is more serious. Speeds of generators and of induction and synchronous motors and of rotary converters can now be only nine hundred, four hundred and fifty, three hundred, two hundred and twenty-five and one hundred and eighty revolutions per minute, or less. The highest speed, nine hundred revolutions per minute, requires a two-pole winding which is apt to be more expensive than multipolar windings. These speeds are in general lower than are desirable for turbo-generators, or for induction motors. Transformers cost more, and incandescent lamps must be made for very low voltage. Aside from trolley circuits and motors there seems little or no reason to favor low frequency.

A twenty-five cycle standard single-phase railway motor will run on fifteen cycles with an increased output of some fif-

teen or twenty percent. A fifteen cycle motor having the same weight as a twenty-five cycle motor, has about thirty percent to forty percent greater output, with higher efficiency and power-factor. A fifteen cycle locomotive, or a fifteen cycle multiple-unit train, having the same power in motors as twenty-five cycle equipments, will have better performance and lower cost. But these are not all. Permissible lengths of rigid wheel base and diameters of driving wheels of locomotives and the ordinary sizes of car trucks place a limit on motor dimensions. The low frequency enables larger outputs to be secured within given dimensions. Hence capacity as well as cost is a factor.

If the problem is considered as relating simply to the operation of heavy trains by single-phase motors, fifteen cycles has little opposition. The estimated increase of ten percent in turbo-generator cost is quickly wiped out by the less cost of motors. Troubles come when the side issues appear. The lower frequency is not so useful for running stationary induction motors nor for station and car and shop lighting; it does not permit convenient power supply from twenty-five cycle plants. The best frequency in a particular case depends upon the relative importance of the motor equipments and of the other things. In the beginning when the traction element has less relative importance than it may have later there will often appear strong reasons for adopting twenty-five cycles. In such cases the probability of future extensions and inter-traffic with fifteen cycle loads must be taken into account. Fortunately, fifteen cycle equipments may run from a twenty-five cycle trolley, though with decreased capacity, and twenty-five cycle equipments may be operated from fifteen cycles provided the transformers be designed for the lower frequency. Again, twenty-five cycle motors and transformers can without modification be operated at reduced capacity on fifteen cycles if the trolley circuit have about two-thirds the voltage used on twenty-five cycles This method may be useful on some occasions as an emergency expedient. Frequency changers may be placed between twenty-five cycle or sixty cycle and low frequency circuits. Aside from objections of cost and losses, they have several merits. The transmission may be three-phase, at a uniform and high power-factor and the single-phase low frequency current may have an independent voltage control. This would avoid a single-phase fluctuating load with variable power-factor on the three-phase system. Frequency changers need not be placed in all sub-stations. The low frequency current may be transmitted to

transformer sub-stations.

Altogether, therefore, it is evident that the question of frequency is by no means a simple one, if considerations aside from the motors are deemed important. The general discussion of the broad question is quite timely. From the standpoint of the railroad the question is substantially this,—Is the problem purely a traction problem? If it is, fifteen cycles is the recommended frequency. If it is not, if other features of the situation make it convenient to take current from a twenty-five cycle system, then the proper course to pursue is not always obvious.

CHAS. F. SCOTT

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**An Engineer's Philosophy**

Professor Karapetoff's article printed in this number of the JOURNAL is addressed primarily to young engineers. It deals, however, with questions of intense and vital interest, and merits being studied deeply by all men.

The address presents in a clear-cut, systematic way a scheme of ordering one's life which, if followed, will build up character, widen the view of one's work and lead to personal satisfaction—which is happiness.

The young man just entering upon a business career should in particular earnestly study that section of the address dealing with the necessity of a working theory of life. Too many are prone to drift along without a definite purpose and aim. All may not fully accept the rules laid down and the conclusions reached by the author of the address but if every young man will adapt the rules to his own case or plan out similar rules and follow them, he will surely go farther and with more satisfaction than by merely taking things at haphazard as they come along.

H. D. SHUTE

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**Drop In Alternating-Current Circuits**

The practical value of the classic article on "Drop in Alternating-Current Circuits," by Mr. Mershon, amply justifies its reprinting in the JOURNAL. The supplemental examples in the article by Mr. Fowler will prove useful and instructive to those who have not a working familiarity with the principles involved. These examples cover a considerable range so that it should not be difficult to apply this method to the solution of any problem which is likely to arise.

# RAILWAY SIGNALING—II. (Continued)

## ELECTRO-PNEUMATIC INTERLOCKING

W. H. CADWALLADER

### PNEUMATIC AND ELECTRIC CONNECTIONS

The pipes for carrying the compressed air are of galvanized iron and are tested under greater pressure than they are ever called upon to stand under ordinary working conditions. The main air pipe is provided with expansion joints suitably placed, to take care of any expansion or contraction due to change in temperature. Gate valves are also installed along the line for shutting off the air at any desired place in case of a break in the pipe without the necessity of shutting down the compressors and completely "tying

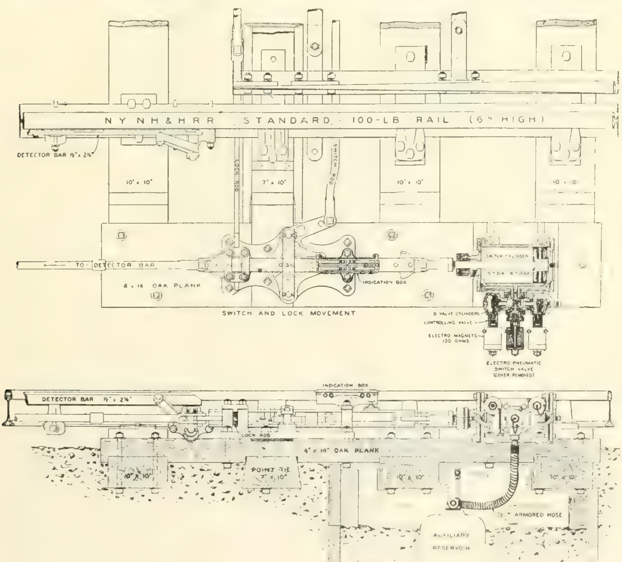


FIG. 5—PLAN AND ELEVATION OF SIMPLE SWITCH

up" the plant. The branch connections are also provided with stop cocks so that the air can be shut off at any particular switch or sig-

nal at any time without interfering with any of the others. The pipes are usually encased in wooden conduits and placed under ground, those crossing tracks being placed deep enough to prevent any disturbance by section men when raising or lowering tracks or tamping ties.

The wires from the machine for controlling the various functions are usually carried in yellow pine conduit or "trunking" to protect them from mechanical injury. This conduit is usually supported on oak stakes or foundations about six inches above the ground, although it is sometimes buried so as to come level with the top of the ground. The former method is preferable to the latter

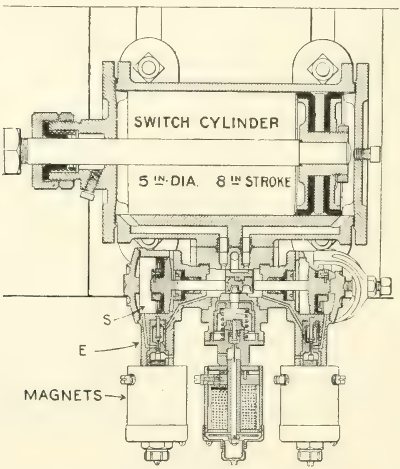


FIG. 6—SECTIONAL VIEW OF CYLINDER AND VALVE

being much easier of access and more apt to be free from moisture. The insulated wires between the machine and the various functions are usually made up in five conductor cables, as five wires are required for the control of each switch or crossover and the signals are usually so located that a cable can be used to advantage for two of them. The conductors of these cables are made of different colors so that the five conductors can be easily distinguished. A percentage of spare wires is usually provided for use in case of breaks or grounds. Terminal boxes are installed at frequent intervals

which form convenient places for conducting tests and for making joints, as no splices are allowed in the conduits.

SWITCHES—LOCKS—SIGNALS

The switches are operated by switch and lock movements actuated from air cylinders of suitable size. Both the cylinders and movements are rigidly attached to iron plates which in turn are bolted to the switch ties of the switch to be operated. Working in conjunction with each switch is a "detector" bar, the operation and function of which was described in the article treating on mechanical interlocking.* Fig. 5 shows such a movement and detector applied to a single switch. The switch and lock movement has a total stroke of eight inches. The first two inches of its movement unlocks the switch and throws the detector bar, the next four inches

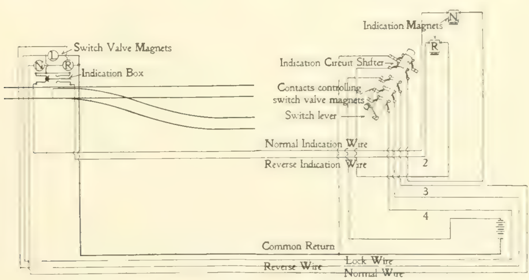


FIG. 7—CONNECTIONS FOR A SINGLE SWITCH CIRCUIT

shifts the switch from one position to the other and the last two inches locks it in its new position.

An electric switch valve which controls the admission of air to, or the discharge of air from, the cylinder is attached to each switch cylinder. In one of the chambers of the switch valve, and constantly under pressure is a slide valve mounted in a manner similar to that of a steam engine. The valve lies between the ends of two small plungers extending from the pistons of two single acting cylinders which are each provided with a separate magnet and pin valve to control their movement. The air for these pin valves is forced through a port drilled from their chamber to that of the slide valve. In practice one or the other of the pin valve magnets is energized by current from the tower at all times. Consequently

*See *The Electric Journal,* Vol. IV., p. 10, January, 1907.

the pressure is always against one or the other of the pistons used for shifting the slide valve. A pneumatic bolt lock is applied to the slide valve and it is absolutely necessary that this be withdrawn before the valve can be operated. This bolt lock consists of a balanced piston the plunger of which is normally forced into a recess in the slide valve by the action of a coil spring. The air pressure is normally confined to the cylinder both above and below the piston, the former by a pin valve controlled by an electro-magnet. When the magnet is energized, the air is exhausted from above the piston and the pressure below it raises it, compresses the coil spring and lifts the bolt lock from the slide valve. When the magnet is again de-energized further escape of air from above the piston is prevented and the coil spring again forces the bolt lock into the slide valve. A sectional view of a cylinder and valve is shown in Fig 6. Cylin-

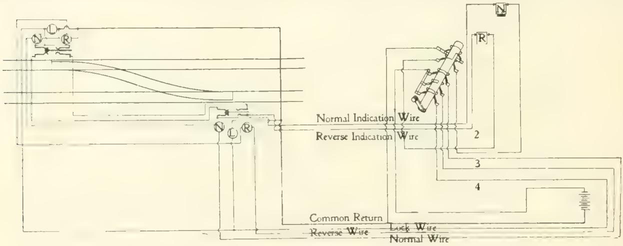


FIG. 8—CONNECTIONS FOR CROSS-OVER CIRCUIT

ders for the operation of single switches are usually five or six inches in diameter, and for the operation of slip switches and movable point frogs, seven and one-half inches. One end of a double slip and the movable frog are generally operated from the same cylinder, the cylinder being placed at the frog points, working them through two switch and lock movements coupled in tandem, and by mechanical connections working the slip points through a single switch and lock movement at the slip end. When hooked up in this manner, the switch indication box is placed on the movement farthest away from the cylinder.

In addition to the five wires mentioned previously as being required for the control of a switch, there is a common return wire for the entire interlocking. The wires are known by the function they control, viz.—a normal, a reverse and a lock control; a normal and a reverse indication. The circuits for a single switch are shown in Fig. 7. By referring to this diagram it may be seen that the first

movement of the lever in the machine energizes the centre or "lock" magnet on the switch valve before the circuit is broken on the reverse magnet, and by so doing withdraws the bolt lock from the slide valve. Continuing this movement energizes the reverse shifting magnet, and by unseating a pin valve admits the air to the reverse auxiliary cylinder, at the same time de-energizing the normal magnet and releasing the air in the normal auxiliary cylinder, thereby moving the slide valve to the opposite side by means of the piston

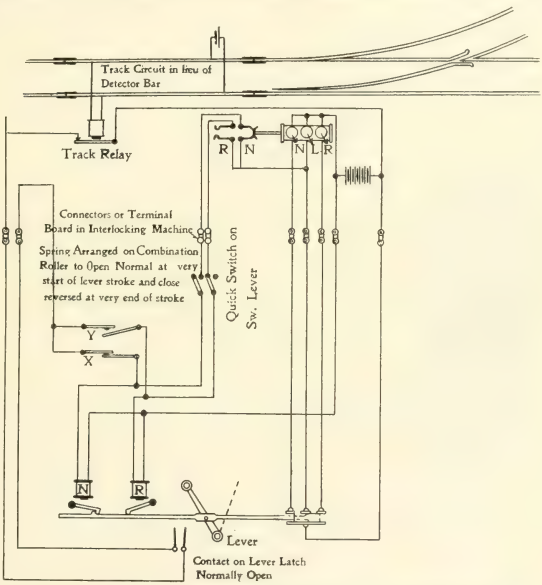


FIG. 9—CONNECTIONS FOR A SINGLE SWITCH, USING TRACK CIRCUIT IN LIEU OF DETECTOR BAR

and piston rod. The shifting of the slide valve in turn transfers the air pressure from one end of the cylinder to the other and throws the switch, through the medium of the switch and lock movement.

When a switch is normal as shown at Fig. 7 the first movement of the lever to the reverse position breaks the normal indication magnet control on the machine and drops the armature and latch. The last movement of the switch closes the reverse indication control circuit through the indication box contact springs, showing that

the switch has been shifted and locked in its new position, lifts the armature and latch, and releases the segment which allows the lever to be placed in the extreme reverse position and the latch dropped. The placing of the lever in the extreme reverse position also releases any mechanical locking that may depend on that particular lever. The moving of a switch in the opposite direction reverses the order of these operations. When two or more switches are operated from one lever by two independent cylinders— as for example a crossover —the indication circuit is carried through indication boxes on each movement in series as shown in Fig 8.

From the above description, it is apparent that the objections offered to the use of switch and lock movements in mechanical work, viz:—the small stroke available for locking the switch, the danger of forcing the lever completely over through lost motion in the connections, and that a switch may not correspond to the position of its lever due to broken connections, do not hold good in the electro-pneumatic interlocking system, as a positive indication must be received in the tower that the switch has make its complete stroke and has been locked, before its lever can be put to the full normal or reverse position.

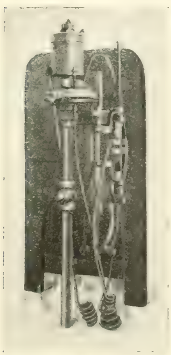

FIG. 10—SIGNAL MOVEMENT AND CIRCUIT BREAKER

In many cases "electric detector" circuits are installed in lieu of the mechanical detector bars, in which case, a short section of track is insulated ahead of the switch, and the indication wire passed through a relay contact, the relay being actuated by a battery connected to the rails of the track. Where "detector circuits" are used the switch lever is equipped with a latch circuit controller similar to the one applied to signal levers, which closes a circuit on the indication magnet through the relay contact. This is illustrated in Fig. 8. From a reference to this figure it is obvious that both the normal and reverse indication magnets are normally on open circuit, and either one is energized by the first movement of the lever latch providing the "track section" is unoccupied.

High signals are of iron pipe construction. The spectacle casting carrying the semaphore arm and the colored glass for night indication are so counterweighed as to always gravitate to the "danger" or "stop" position. Hence it is only necessary to use a single stroke

cylinder to work against gravity for the operation of signals, and indicate to the operator in the tower, that the signal is in the "stop" position.

Signal cylinders are ordinarily three inches in diameter, and are fitted with an electro-magnet and valve for the controlling of the admission and discharge of air. At the side of each cylinder is clamped a circuit breaker so arranged that the circuit is made only when the signal is at "danger." A signal movement and circuit breaker are shown in Fig. 10.

As previously stated, each signal lever in the machine is equipped with a latch circuit controller, the object of which is to close a contact as soon as the latch is raised, thereby completing a circuit

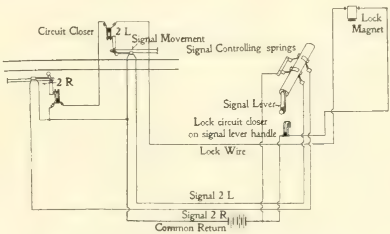


FIG. 11—DIAGRAM OF SIGNAL CIRCUITS

through the circuit controller on the signal cylinder and the lock magnet on the machine, and by so doing lift the armature and latch, release the segment and allow the lever to be moved to the right or left, depending on the mechanical locking and signal to be operated. The movement of the lever closes the circuit controlling the magnet on the signal cylinder through one of the bronze bands on the roller. The magnet in turn opens the valve and allows the air to enter the cylinder and clear the signal. A diagram of signal circuits is shown in Fig. 11. This diagram shows that when more than one signal is controlled from the same lever the lock wire is carried through circuit breakers on each of the signals so that it is absolutely necessary for all of them to be at "danger" before the lock magnet can be energized and the lever restored to its normal position.

Low or dwarf signals—used between tracks—are operated by means of direct acting cylinders, which act against strong coil springs so arranged as to be compressed when air is applied to the cylinders, in clearing the signals and to force the signals back to

"danger" when the air pressure is removed. Dwarf cylinders differ from those of high signals in that they are movable and their pistons are stationary. Their piston rods are hollow and serve as ports for the admission and discharge of air to and from the cylinder. The cylinder is directly connected to the semaphore shaft by means of a rod enclosed in the post. Fig. 12 shows a sectional view of a dwarf signal. At the side of each dwarf signal cylinder but insulated therefrom is a brass plate which closes a circuit when the signal is in the stop position by resting against contact springs fastened to

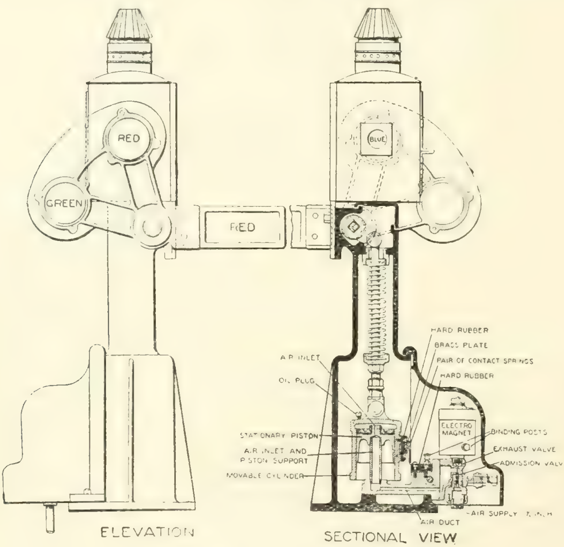


FIG. 12—DWARF SEMAPHORE SIGNAL

the base of the signal. This circuit controller performs the same functions as the one previously described in connection with the high signal.

In mechanical work, it is not considered good or safe practice to operate more than one signal from one lever although two or more can be so operated through what is known as a "selector." It is sufficient here to say that selectors in mechanical work are very unsatisfactory and unreliable. In electro-pneumatic interlocking

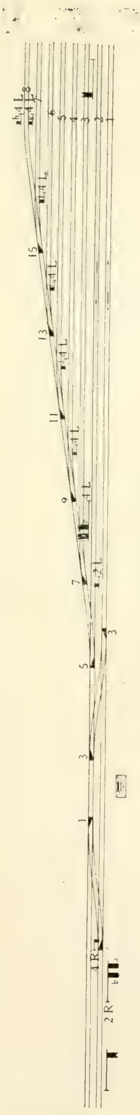

FIG. 13—LAYOUT OF TRACKS

this selection is done electrically in the tower through the "combination" on the hard rubber roller of the machine levers. Opposing signals for the same track, or signals that govern traffic up to the same track from converging tracks, may be worked with perfect safety from the same lever in the electro-pneumatic interlocking system. As a means of illustrating how this selecting is accomplished, the layout shown in Fig. 13 is assumed. Previous mention was made that the normal position of signal levers is in the central position and that they are capable of being moved to the right or left. By reference to Fig. 11 it may be seen how opposing signals for the same track are operated from a right or left hand movement of the lever. By referring to Fig. 13 it may be seen that but one train can move out of the yard to the main track at any one time and the signals governing movements to the main track are all operated from the same lever, shown as No. 4. Here is where the "combination" on the electro-pneumatic machine is used to advantage for, by it, current is supplied to the desired signal. The "combination" for the above layout is shown in Fig. 14. If, for exemple, it is desired to clear the signal on track *5*, it is first necessary to reverse switches *5* and *11*, so that the track will be in shape for the train to proceed over it. Signal lever *4* is then moved to the left, which will energize magnet on signal *4Lc*, through closed circuit breakers on levers *5*, *7*, *9*, and *11*. A study of the layout and combination will show that any one of the signals can be given through the contacts on the rollers of the switch levers.

AUXILIARY APPLIANCES

The control of annunciators is accomplished by means of a section of bonded and insulated track at the distance from the tower at which it is desired to announce an approaching train. At one

end of this insulated section is located the battery and at the other a relay. The annunciator magnet control is carried through a contact on this relay. As soon as a train strikes this bonded section the relay is shunted. This in turn opens the annunciator control and causes the miniature signal to assume the "danger position" and the

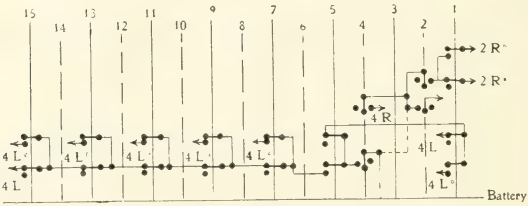


FIG. 14—"COMBINATION" FOR TRACK LAYOUT SHOWN IN FIG. 13

annunciator in so moving closes a circuit on a single stroke bell, thus indicating to the towerman that a train is approaching.

Track sections are also installed for automatically setting signals to the "danger" or "stop" position, after a train has passed them and preventing them from again being cleared as long as the train is on the track section, but this feature will be dealt with in a later article.

# DROP IN ALTERNATING-CURRENT LINES*

RALPH D. MERSHON

WHEN alternating currents first came into use, when transmission distances were short and the only loads carried were lamps, the question of drop or loss of voltage in the transmitting line was a simple one, and the same methods as for direct current could without serious error be employed in dealing with it. The conditions existing in alternating practice to-day—longer distances, polyphase circuits and loads made up partly or wholly of induction motors—render this question less simple, and direct-current methods applied to it do not lead to satisfactory results. The results, if any, must be in available and convenient form. In what follows, the endeavor has been made to treat the subject of drop in alternating-current lines, so that if the reader be grounded in the theory the brief space devoted to it will suffice, but if he do not comprehend or care to follow the simple theory involved he may nevertheless turn the results to his practical advantage.

## CALCULATION OF DROP

Most of the matter heretofore published on the subject of drop treats only of the inter-relation of the e. m. f.'s involved, and, so far as the writer knows, there have not appeared in convenient form the data necessary for accurately calculating this quantity. The table and the chart opposite it include in a form suitable for the engineer's pocket-book everything necessary for calculating the drop of alternating-current lines.

The chart is simply an extension of the vector diagram (Fig. 1), giving the relations of the e. m. f.'s of line, load and generator. In Fig. 1, $E$ is the generator e. m. f., $e$ the e. m. f. impressed upon the load; $c$ that component of $E$ which overcomes the back e. m. f. due to the impedance of the line. $c$ is made up of two components at right angles to each other. One is $a$, the component overcoming the $CR$ or back e. m. f. due to resistance of the line. The other is $b$, the component overcoming the reactance or back e. m. f. due to the alternating field set up around the wire by the current in the wire. The drop is the difference between $E$ and $e$. It is $d$, the radial distance between two circular arcs, one of which is drawn with a radius, $e$, and the other with a radius, $E$.

*Reprinted from *The American Electrician.*

## TABLE FOR CALCULATING THE DROP IN ALTERNATING-CURRENT LINES

By means of the table calculate the *Resistance-Volts* and the *Reactance-Volts* in the line, and find what percent each is of the e.m.f. delivered at the end of the line. Starting from the point on the chart where the vertical line corresponding with power-factor of the load intersects the smallest circle lay off in percent the resistance e.m.f. horizontally and to the right; from the point thus obtained lay off upward in percent the reactance-e.m.f. The circle on which the last point falls gives the drop in percent of the e.m.f. delivered at the end of the line. Every tenth circle arc is marked with the percent drop to which it corresponds.

| Size of Wire B. & S. | Weight in Lbs. | Resistance Volts of Line for one ampere | Reactance-Volts of line for one ampere at 60 cycles per second for the distances given, between centers of conductors | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ½″ | 1″ | 2″ | 3″ | 6″ | 9″ | 12″ | 18″ | 24″ | 30″ | 36″ |
| | | | **1000 FEET OF LINE** (2000 feet of Wire) | | | | | | | | | | |
| 0000 | 1278 | .098 | .046 | .079 | .111 | .130 | .161 | .180 | .193 | .212 | .225 | .235 | .244 |
| 000 | 1014 | .124 | .052 | .085 | .116 | .135 | .167 | .185 | .199 | .217 | .230 | .241 | .249 |
| 00 | 804 | .156 | .057 | .090 | .121 | .140 | .172 | .190 | .204 | .222 | .236 | .246 | .254 |
| 0 | 638 | .197 | .063 | .095 | .127 | .145 | .177 | .196 | .209 | .228 | .241 | .251 | .259 |
| 1 | 506 | .248 | .068 | .101 | .132 | .151 | .183 | .201 | .214 | .233 | .246 | .256 | .265 |
| 2 | 402 | .313 | .074 | .106 | .138 | .156 | .188 | .206 | .220 | .238 | .252 | .262 | .270 |
| 3 | 318 | .394 | .079 | .112 | .143 | .162 | .193 | .212 | .225 | .244 | .257 | .267 | .275 |
| 4 | 252 | .497 | .085 | .117 | .149 | .167 | .199 | .217 | .230 | .249 | .262 | .272 | .281 |
| 5 | 200 | .627 | .090 | .121 | .154 | .172 | .204 | .223 | .236 | .254 | .268 | .278 | .286 |
| 6 | 158 | .791 | .095 | .127 | .158 | .178 | .209 | .228 | .241 | .260 | .272 | .283 | .291 |
| 7 | 126 | .997 | .101 | .132 | .164 | .183 | .214 | .233 | .246 | .265 | .278 | .288 | .296 |
| 8 | 100 | 1.260 | .106 | .138 | .169 | .188 | .220 | .238 | .252 | .270 | .284 | .293 | .302 |
| | | | **ONE MILE OF LINE** (Two miles of Wire) | | | | | | | | | | |
| 0000 | 6752 | .518 | .243 | .417 | .586 | .687 | .850 | .951 | 1.02 | 1.12 | 1.19 | 1.24 | 1.29 |
| 000 | 5354 | .653 | .275 | .449 | .613 | .713 | .882 | .977 | 1.05 | 1.15 | 1.22 | 1.27 | 1.32 |
| 00 | 4246 | .824 | .301 | .475 | .639 | .739 | .908 | 1.00 | 1.08 | 1.17 | 1.25 | 1.30 | 1.34 |
| 0 | 3370 | 1.04 | .332 | .502 | .671 | .766 | .935 | 1.04 | 1.10 | 1.20 | 1.27 | 1.33 | 1.37 |
| 1 | 2670 | 1.31 | .359 | .533 | .687 | .797 | .966 | 1.06 | 1.13 | 1.23 | 1.30 | 1.35 | 1.40 |
| 2 | 2118 | 1.65 | .391 | .560 | .728 | .824 | .993 | 1.09 | 1.16 | 1.26 | .133 | 1.38 | 1.43 |
| 3 | 1680 | 2.08 | .417 | .591 | .755 | .856 | .102 | 1.12 | 1.19 | 1.29 | 1.36 | 1.41 | 1.45 |
| 4 | 1332 | 2.63 | .449 | .618 | .787 | .882 | 1.05 | 1.15 | 1.22 | 1.32 | 1.38 | 1.44 | 1.48 |
| 5 | 1056 | 3.31 | .475 | .639 | .813 | .908 | 1.08 | 1.18 | 1.25 | 1.34 | 1.42 | 1.47 | 1.51 |
| 6 | 838 | 4.18 | .502 | .671 | .834 | .940 | 1.10 | 1.20 | 1.27 | 1.37 | 1.44 | 1.49 | 1.54 |
| 7 | 664 | 5.27 | .533 | .697 | .866 | .966 | 1.13 | 1.23 | 1.30 | 1.40 | 1.47 | 1.52 | 1.56 |
| 8 | 526 | 6.64 | .560 | .729 | .893 | .993 | 1.16 | 1.26 | 1.33 | 1.43 | 1.50 | 1.55 | 1.60 |

Note— To find the weight of wire for a three-phase circuit, add fifty percent to the value given in the table.

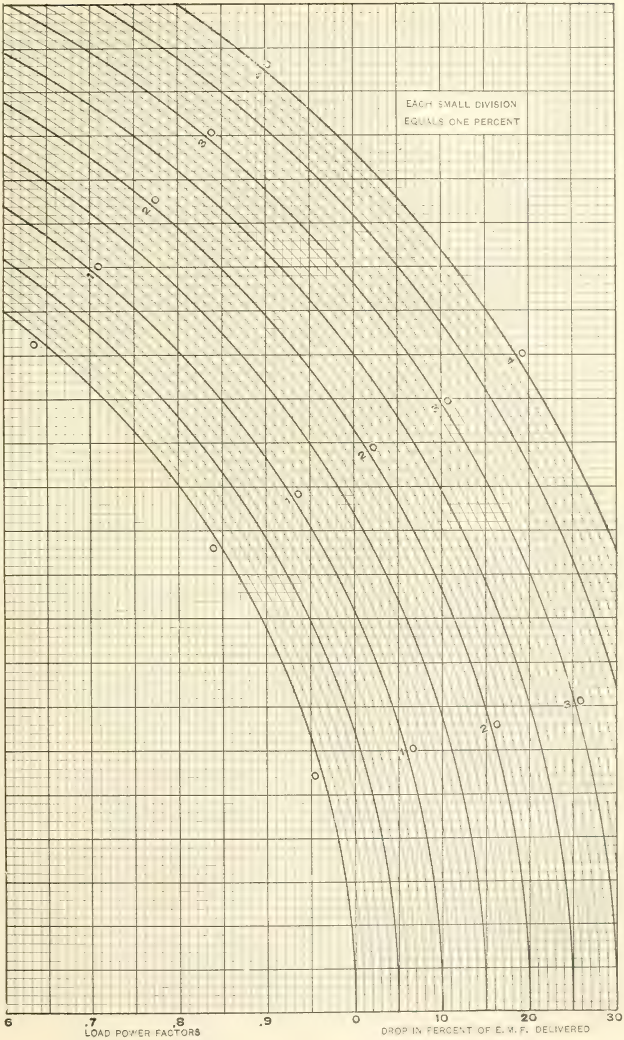


CHART FOR CALCULATING THE DROP IN ALTERNATING-CURRENT LINES

The chart is made by striking a succession of circular arcs with *O* as a center. The radius of the smallest circle corresponds to *e*, the e. m. f. of the load, which is taken as 100 percent. The radii of the succeeding circles increase by one percent of that of the smallest circle, and, as the radius of the last or largest circle is 140 percent of that of the smallest, the chart answers for drops up to 40 percent of the e. m. f. delivered.

The terms resistance-volts, resistance-e. m. f., and reactance-volts, reactance-e. m. f., refer, of course, to the voltages for overcoming the back e. m. f.'s due to resistance and reactance respectively. The figures given in the table under the heading "Resistance-Volts for One Ampere, etc.," are simply the resistances of 2 000 feet of the various sizes of wire. The values given under the heading "Reactance-Volts, etc.," are, a part of them, calculated from tables pub-

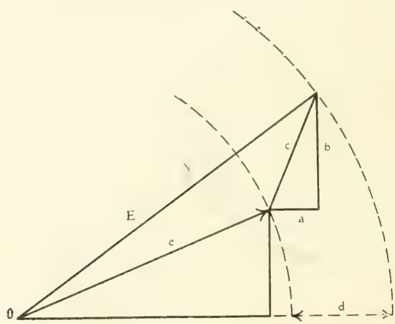


FIG. 1—VECTOR DIAGRAM GIVING RELATIONS OF LINE, LOAD AND GENERATOR ELECTRO-MOTIVE FORCES

lished by Messrs. Houston & Kennelly. The remainder were obtained by using Maxwell's formula.

The explanation given in the table accompanying the chart is thought to be a sufficient guide to its use, but a few examples may be of value.

*Problem*—Power to be delivered, 250 kw; e m. f. to be delivered, 2 000 volts; distance of transmission, 10 000 feet; size of wire, No. 0; distance between wires, 18 inches; power-factor of load, 0.8; frequency, 7 200 alternations per minute.—Find the line loss and drop.

Remembering that the power-factor is that fraction by which the apparent power of volt-amperes must be multiplied to give the true power, the apparent power to be delivered is

$$\frac{250 \text{ kw}}{0.8} = 312.5 \text{ apparent kw.}$$

The current, therefore, at 2 000 volts will be

$$\frac{312\,500}{2\,000} = 156.25 \text{ amperes.}$$

From the table of reactances under the heading "18 inches," and corresponding to No. 0 wire, is obtained the constant 0.228. Bearing the instructions of the table in mind, the reactance-volts of this line are, 156.25 (amperes) $\times$ 10 (thousands of feet) $\times$ 0.228=356.3 volts, which are 17.8 percent of the 2 000 volts to be delivered.

From the column headed "Resistance-volts," and corresponding to No. 0 wire, is obtained the constant 0.197. The resistance-volts of the line are, therefore, 156.25 (amperes) $\times$ 10 (thousandths of feet) $\times$ 0.197=307.8 volts, which are 15.4 percent of the 2 000 volts to be delivered.

Starting, in accordance with the instructions of the table from the point where the vertical line, which, at the bottom of the table is marked "Load Power Factor" 0.8, intersects the inner or smallest circle, lay off horizontally and to the right the resistance-e. m. f. in per cent (15.4) and from the point thus obtained lay off vertically the reactance-e. m. f. in percent (17.8). The last point falls at about 23 per cent, as given by the circular arc. This, then, is the drop in percent of the e. m. f. delivered. The drop in percent of the generator e. m. f. is, of course,

$$\frac{23}{100+23} = 18.7 \text{ percent.}$$

The percentage loss of power in the line has not, as with direct current, the same value as the percentage drop. This is due to the fact that the line has reactance and also that the apparent power delivered to the load is not identical with the true power—that is, the load power-factor is less than unity. The loss must be obtained by calculating $C^2$ R for the line, or, what amounts to the same thing, by multiplying the resistance volts by the current.

The resistance-volts in this case are 307.8 and the current

156.25 amperes. The loss is $307.8 \times 156.25 = 48.1$ kw. The percentage loss is

$$\frac{48.1}{250+48.1}=16.1 \text{ percent.}$$

Therefore, for the problem taken, the drop is 18.7 percent and the loss is 16.1 percent. If the problem be to find the size wire for a given drop, it must be solved by trial. Assume a size of wire and calculate the drop; the result in connection with the table will show the direction and extent of the change necessary in the size of wire to give the required drop.

The effect of the line reactance in increasing the drop should be noted. If there were no reactance the drop in the above example would be given by the point obtained in laying off on the chart the resistance-e. m. f. (15.4) only. This point falls at 12.4 percent and the drop in terms of the generator e. m. f. would be

$$\frac{12.4}{112.4}=11 \text{ percent, instead of } 18.7 \text{ percent.}$$

Anything, therefore, which will reduce reactance is desirable.

Reactance can be reduced in two ways. One of these is to diminish the distance between wires. The extent to which this can be carried is limited in the case of a pole line to the least distance at which the wires are safe from swinging together in the middle of the span; in inside wiring by the danger from fire. The other way of reducing reactance is to split the copper up into a greater number of circuits and arrange these circuits so that there is no inductive interaction. For instance, suppose that in the example worked out above, two No. 3 wires were used instead of one No. 0 wire. The resistance-volts would be practically the same, but the reactance-volts would be less in the ratio

$0.5 \times \frac{0.244}{0.228} = 0.535$, since each circuit would bear half the current the No. 0 circuit does, and the constant for No. 3 wire is 0.244 instead of 0.228—that for No. 0. The effect of subdividing the copper is also shown if in the example given it is desired to reduce the drop to, say, one-half. Increasing the copper from No. 0 to No. 0000 will not produce the required result for, although the resistance-volts will be reduced one-half, the reactance-volts will be reduced only in the ratio $\frac{0.212}{0.228}$. If, however, two inductively independent circuits

of No. 0 wire be used, the resistance and reactance-volts will both be reduced one-half and the drop will therefore be diminished the required amount.

*The component of drop due to reactance is best diminished by subdividing the copper or by bringing the conductors closer together. It is little affected by change in size of conductors.*

An idea of the manner in which changes of power-factor affect drop is best gotten by an example. Assume distance of transmission, distance between conductors, e.m.f. and frequency the same as in the previous example. Assume the apparent power delivered the same as before, and let it be constant, but let the power-factor be given several different values; the true power will, therefore, be a variable depending upon the value of the power-factor. Let the size of the wire be No. 0000. As the apparent power, and hence the current, is the same as before, and the line resistance is one-half, the resistance-e.m.f. in this case will be

$$\frac{15.4}{2}, \text{ or } 7.7 \text{ percent of the e. m. f. delivered.}$$

Also, the reactance-e. m. f. will be

$$\frac{0.212}{0.228} \times 17.8 = 16.5 \text{ percent.}$$

Combining these on the chart for a power-factor of 0.4 and deducing the drop in percent of the generator e. m. f., the value obtained is 15.3 percent; with a power-factor of 0.8 the drop is 14 percent; with a power-factor of unity it is 8 percent. If in this example the true power, instead of the apparent power had been taken as constant, it is evident that the values of drop would have differed more widely, since the current, and hence the resistance and reactance-volts, would have increased as the power-factor diminished. The condition taken more nearly represents that of practice.

If the line had resistance and no reactance, the several values of drop, instead of 15.3, 14 and 8, would be 3.2, 5.7 and 7.2 percent, respectively, showing that for a load of lamps the drop will not be much increased by reactance, but that with a load, such as induction motors, whose power-factor is less than unity, care should be taken to keep the reactance as low as practicable. In all cases it is advisable to place conductors as close together as good practice will permit.

When there is a transformer in circuit, and it is desired to obtain the combined drop of transformer and line, it is necessary to

know the resistance and reactance-volts of the transformer. The resistance-volts of the combination of line and transformer are the sum of the resistance-volts of the line and the resistance-volts of the transformer. Similarly the reactance-volts of the line and transformer are the sum of their respective reactance-volts. The resistance and reactance-e. m. f.'s of transformers may usually be obtained from the makers and are ordinarily given in percent.* These percentages express the values of the resistance and reactance-e.m.f.'s when the transformer delivers its normal full-load current and they express these values in terms of the normal no-load e.m.f. of the transformer.

Consider a transformer built for transformation between 1 000 and 100 volts. Suppose the resistance and reactance-e. m. f.'s given are two percent and seven percent respectively. Then the corresponding voltages when the transformer delivers full-load current are 2 and 7 volts, or 20 and 70 volts, according as the line whose drop is required is connected to the low-voltage or high-voltage terminals. These values, 2—7 and 20—70, hold, no matter at what voltage the transformer is operated, since they depend only upon the strength of current, providing it is of the normal frequency. If any other than the full-load current is drawn from the transformer the reactance and resistance-volts will be such a proportion of the values given above as the current flowing is of the full-load current. When the resistance and reactance-volts of a transformer are known, its regulation may be determined by making use of the chart in the same way as for a line having resistance and reactance.

As an illustration of the method of calculating the drop in a line and transformer, and also of the use of table and chart in calculating low voltage mains, the following example is given:

*Problem*—A single-phase induction motor is to be supplied

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*When the required values cannot be obtained from the makers they may be measured. Measure the resistance of both coils. If the line to be calculated is attached to the high-voltage terminals of the transformer, the equivalent resistance is that of the high-voltage coil plus the resistance obtained by increasing in the square of the ratio of transformation the measured resistance of the low voltage coil. That is, if the ratio of transformation is 10 the equivalent resistance referred to the high-voltage circuit is the resistance of the high-voltage coil, plus 100 times that of the low-voltage coil. This equivalent resistance multiplied by the high-voltage current gives the transformer resistance-volts referred to the high-voltage circuit. Similarly, the equivalent resistance referred to the low-voltage circuit is the resistance of the low-voltage

with 20 amperes at 200 volts; alternations, 7 200 per minute; power-factor, 0.78. The distance from transformer to motor is 150 feet, and the line is No. 5 wire, 6 inches between centers of conductors. The transformer reduces in the ratio

$\frac{2000}{200}$, has a capacity of 25 amperes at 200 volts, and when

delivering this current and voltage its resistance-e. m. f. is 2.5 percent, its reactance-e.m.f. 5 percent. Find the drop.

The reactance of 1 000 feet of circuit consisting of two No. 5 wires, six inches apart, is 0.204. The reactance volts, therefore, are

$$0.204 \times \frac{150}{1\,000} \times 20 = 0.61 \text{ volts.}$$

The resistance-volts are

$$0.627 \times \frac{150}{1\,000} \times 20 = 1.88 \text{ volts.}$$

At 25 amperes the resistance-volts of the transformer are 2.5 percent of 200, or 5 volts. At 20 amperes they are

$\frac{20}{25}$ of this, or 4 volts.

Similarly, the transformer reactance-volts, at 25 amperes, are 10, and at 20 amperes are 8 volts. The combined reactance-volts of transformer and line are $8+0.61=8.61$, which is 4.3 percent of the 200 volts to be delivered. The combined resistance-volts are $1.88+4$, or 5.88, which is 2.94 percent of the e. m. f. to be delivered. Combining these quantities on the chart with a power-factor of 0.78, the drop is 5 per cent of the delivered e. m. f.

$$\text{or } \frac{5}{105} = 4.8 \text{ percent}$$

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coil, plus that of the high-voltage coil reduced in the square of the ratio of transformation. It follows, of course, from this that the values of the resistance-volts referred to the two circuits bear to each other the ratio of transformation. To obtain the reactance volts, short-circuit one coil of the transformer and measure the voltage necessary to force through the other coil its normal current at normal frequency. The result is, nearly enough, the reactance-volts. It makes no difference which coil is short-circuited, as the results obtained in one case will bear to those in the other the ratio of transformation. If a close value is desired, subtract from the square of the voltage reading the square of the resistance-volts, and take the square root of the difference as the reactance-volts.

of the impressed e. m. f. The transformer must be supplied with

$$\frac{2\,000}{0.952} = 2\,100 \text{ volts.}$$

in order that 200 volts shall be delivered to the motor.

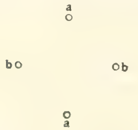


FIG. 2—TWO-PHASE CIRCUITS ARRANGED DIAGONALLY TO ELIMINATE INDUCTIVE INTERACTION.

The table is made out for 7 200 alternations, but will answer for any other number if the values for reactance be changed in the direct proportion to the change in alternations. For instance for 16 000 alternations multiply the reactances given by 16 000÷7 200. For other distances between centers of conductors interpolate the values given in the table. As the reactance values for different sizes of wire change by a constant amount, the table can, if desired, be readily extended for larger or smaller conductors.

The table is based on the assumption of sine currents and e. m. f.'s. The best practice of today produces machines which so closely approximate this condition that results obtained by the above methods are well within the limits of practical requirements.

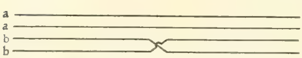


FIG. 3—TRANSPOSITION OF TWO-PHASE CIRCUITS TO ELIMINATE INDUCTIVE INTERACTION

POLYPHASE CIRCUITS

So far, single-phase circuits only have been dealt with. A simple extension of the methods given above adapts them to the calculation of polyphase circuits. A four-wire two-phase transmission may, so far as loss and regulation are concerned, be replaced by two single-phase circuits identical (as to size of wire, distance between wires, current and e. m. f.) with two circuits of the two-phase transmission provided that in both cases there is no inductive interaction between circuits. Therefore, to calculate a four-wire, two-phase transmission, compute the single-phase circuit required to transmit one-half the power at the same voltage. The two-phase transmission will require two such circuits.

A three-wire, three-phase transmission, of which the conductors are symmetrically related, may, so far as loss and regulation are concerned, be replaced by two single-phase circuits having no inductive interaction, and identical with the three-phase line as to size, wire and distance between wires. Therefore, to calculate a three-phase trans-

mission, calculate a single-phase circuit to carry one-half the load at the same voltage. The three-phase transmission will require three wires of the size and distance between centers as obtained for the single-phase.

A three-wire, two-phase transmission may be calculated exactly, as regards loss, and approximately as regards drop, in the same way as for three-phase. It is possible to calculate exactly the drop, but this involves a more complicated method than the approximate one. The error by this approximate method is generally small. It is possible also to get a somewhat less drop and loss with the same copper The error by this approximate method is generally small. It is possible also to get a somewhat less drop and loss with the same copper by proportioning the cross-section of the middle and outside wires of a three-wire, two-phase circuit to the currents they carry, instead of using three wires of the same size. The advantage, of course, is not great, and will not be considered here.


FIG. 4—ARRANGEMENT OF THREE-PHASE CIRCUIT TO ELIMINATE INDUCTIVE INTERACTION.

The above statements as to calculation of polyphase circuits are made subject to certain conditions in arrangements of conductors.

### ARRANGEMENT OF CONDUCTORS

The circuits of a two-phase transmission should be so arranged that there is no inductive interaction. Such arrangement may be accomplished in either of the ways shown in Figs. 2 and 3. Fig 2 shows the two wires, *a a,* of one circuit and the two, *b b,* of the other circuit, at opposite ends of the diagonals of a square. With such an arrangement there is no inductive action between the two circuits, since none of the lines of induction due to the one can be linked through the other. Fig. 3 shows the two circuits side by side (they may be in any other relative position providing it is preserved throughout) and the wires of the circuit, *b b,* interchanged at their middle point. Such an arrangement fulfills the requirements, since all the linkages from *a a,* to *b b,* and from *b b,* to *a a,* in one-half the transmission are exactly offset by the same number of opposite linkages in the other half of the transmission.

The three wires of a three-phase transmission should be so arranged that they are symmetrically related. Figs. 4 and 5 show two

methods of accomplishing this. In Fig. 4 the three wires are at the three corners of an equilateral triangle. In Fig. 5 the wires are all on the same cross arm, and are twice interchanged, once at one-third and once at two-thirds of the transmission distance. In Fig. 4 since the wires bear equal currents, of symmetrical phase relation, and because of the symmetry of arrangement, the inductive action between any one wire and the remaining two is the same, no matter which wire be considered. In Fig. 5 the same is true, as may be seen by tracing the wires throughout their length. The arrangement of Fig. 5 answers for the case of all the power transmitted to the end of the line, and under such conditions only the two transpositions shown are necessary. If power is tapped off at intermediate points and perfect equalization is desired, the wires should be interchanged as shown in Fig. 5, between all points at which there is connection made to the line—that is, there should be two transpositions between the power station and the first receiving station, two between the first and second receiving station, and so on.

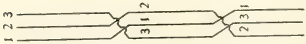

FIG. 5—TRANSPOSITIONS OF THREE-PHASE CIRCUIT TO ELIMINATE INDUCTIVE INTERACTION

In some cases where the triangular arrangement of conductors is employed, the wires are in addition interchanged. This is unnecessary, unless it is not possible to arrange the wires in a triangle, which is practically equilateral, or unless there are two or more circuits adjacent and it is desired to have them inductively independent. The first circuit, *a,* runs straight through; the second, *b,* is interchanged twice; the third, *c,* is interchanged eight times; the fourth would be interchanged twenty-six times, etc. If it is necessary to interchange the first circuit because of inequality in the sides of the triangle, b must be taken as the first circuit, c the second, etc. In Fig. 6, *b* and *c* also answer for the disposition of circuits of which the three wires are on the same cross arm as in Fig. 5; then *b* is the first circuit, *c* the second, etc.

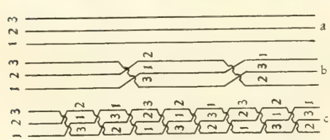


FIG. 6—TRANSPOSITIONS REQUIRED FOR THREE THREE-PHASE CIRCUITS TO RENDER THEM INDUCTIVELY INDEPENDENT

In a two-phase three-wire circuit there is little advantage if any, in arrangement other than that of the wires equidistant and side by

side without interchange. The two circuits of the three-wire, two-phase transmission cannot be made inductively independent, and the complication already mentioned in accurately calculating the drop is due to this fact.

If some such arrangement as those given is not employed—that is, if the four wires of the two-phase or the three of the three-phase are strung straight through on the same cross-arms—the unbalanced inductive action will be the cause of an unbalancing of the system, which in a short transmission may not amount to much, but which in a long transmission may cause considerable annoyance.

The rule given some time back for calculating a three-phase line applies closely but not exactly to Fig. 5. This line cannot be exactly replaced by two single-phase circuits, the wires of which are the same distance apart as the adjacent wires of Fig. 5. No two wires of Fig. 5 are the same distance apart throughout their length. They are one distance apart for two-thirds their length and twice that distance for the remaining third. The equivalent single-phase circuits must, therefore, have between wires a distance intermediate between that of adjacent and extreme wires of Fig. 5. Consider a three-phase line of which adjacent wires are 18 inches apart. The equivalent single-phase circuits must have their wires apart a distance intermediate between 18 inches and 36 inches. What this distance is can be determined by the table of reactances. Suppose the wire be No. 0. The constant for 18 inches is 0.228; that for 36 inches is 0.259. Therefore the constant of the equivalent single-phase circuit is

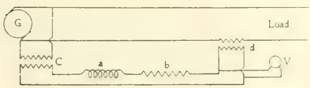


FIG. 7 — DIAGRAM OF CONNECTIONS SHOWING METHOD OF DETERMINING VOLTAGE AT RECEIVING END OF LINE INDEPENDENT OF CURRENT, POWER-FACTOR, REACTANCE AND RESISTANCE

$$\frac{0.228+0.228+0.259}{3}=0.238,$$

which corresponds to a distance of about 22 inches.

This shows one advantage which the triangular arrangement has over that of Fig. 5; for the same distance between adjacent conductors the reactance with the triangular arrangement is less than with that of Fig. 5. If close results are wanted with an arrange-

ment like Fig. 5 the average constant for any two wires must be taken in calculating the reactance volts.

### COMPENSATION FOR DROP

However, the drop in feeders is compensated for, whether by "boosters" or by the use of choke coils or resistances, it is necessary in order to secure good regulation, to have some means of indicating at all times the voltage delivered at the receiving end of the transmission. One of the oldest devices for this purpose is that of using "pressure wires" or leads run from the end of the feeder back to the generating station, where they are attached to a voltmeter. This method was first employed in direct-current work. It answers equally well for alternating currents, providing the two pressure wires are the same distance from any other wires bearing alternating current, or are frequently interchanged so that no inductive effect is upon them.

Pressure wires are objectionable, however, on the score of cost, especially in the case of numerous and long feeders. Other con-

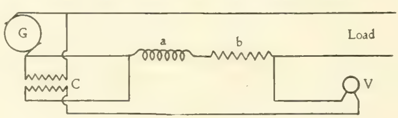


FIG. 8—MODIFICATION OF METHOD SHOWN IN FIG. 7 BY WHICH ONLY VOLTMETER CURRENT IS PASSED THROUGH TRANSFORMER C

trivances, designed to do away with pressure wires, have been used. They depend for their action on the direct or indirect measurement of the current flowing in the feeders, and are supposed to give an indication directly proportional to this current. Although they answer well enough when used on feeders carrying a lamp load only, they are useless on feeders carrying a load of motors or lamps and motors. The reason for this is that with the same current flowing the drop in a line may vary considerably because of variations in the power-factor of the load. This is clearly shown in one of the problems taken up under calculation of drop. The power-factor of a load made up wholly or in part of induction motors will from time to time vary quite widely. This is especially true of a circuit carrying a day load of motors and a night load of lamps.

So far as is known to the writer, there has never been published

a device which will, without regard to the nature of the load, indicate the voltage at the receiving end of an alternating-current line; which will, in other words, take account of current, power-factor, reactance and resistance. Such a device is, however, possible. The apparatus described below, devised by the writer, accomplishes the desired result.

Suppose that at the station there were produced three e.m.f.'s, proportional to and in step with, respectively, the e.m.f. impressed upon the line at the station, the reactance e.m.f. and the resistance e.m.f., and that these three were combined in the same way as are their counterparts in the line. The resultant would be proportional to and in step with the e.m.f. at the distant end of the line, and a voltmeter actuated by this resultant would at all times give an indication proportional to the e.m.f. of the load.

Figs. 7 and 8 show methods of connection which fulfill the required conditions. Many variations from these connections are possible, but they all involve the same principle. In Fig. 7, *d* is a transformer in series with the main line and yielding in its secondary circuit a current always proportional to and in step with the line current. *C* is a transformer connected across the generator terminals and supplying in its secondary circuit an e.m.f. in step with and proportional to that of the generator. *a* is an inductive resistance or reactance coil, and *b* an ohmic resistance, both so adjusted with respect to the current from transformer *d* that for a given current through them their respective e.m.f.'s have the same value relative to the e.m.f. of transformer *C*, as the reactance and resistance e.m.f.'s of the line have to the e.m.f. of the generator. The current supplied by transformer *d* being in step with and proportional to the main current, the reactance-e.m.f. of *a* and the resistance-e.m.f. of *b* will be proportional to and in step with the corresponding quantities of the line, and, with the connections shown in the figure, they will reduce, or cut down, the e.m.f. of *C* in the same proportion as their line counterparts do the generator e.m.f. The voltmeter will, therefore, always give an indication proportional to the voltage delivered at the end of the line. Fig. 8 accomplishes the same result without passing any current through transformer *C*, except that necessary for the voltmeter. This method of indicating the load voltage has proven itself perfectly satisfactory.

# DROP IN ALTERNATING-CURRENT LINES—SPECIFIC EXAMPLES

CLARENCE P. FOWLER

SUPPLEMENTING the preceding article on "Drop in Alternating-Current Lines," by Mr. Ralph D. Mershon, a few concrete examples have been worked out and are here presented to illustrate the use of the table and diagram.

In general, the method of using the table and diagram consists in finding certain definite line data by the aid of the table, which are then used on the diagram to determine the drop. In the accompanying examples a number of specific cases are given with varying conditions of voltage, energy, power-factor, number of phases, frequency, size of wire, distance between wires and length of circuit.

## EXAMPLE I—SINGLE-PHASE

In the first example it is required to deliver 1 000 real kw at 10 000 volts and 80 percent power-factor over a ten-mile single-phase line composed of No. 0 B. & S. copper wire at a frequency of 25 cycles per second, the distance between wires being 36 inches. The apparent kw is obtained by dividing the real kw by the power-factor, hence $10\,000 \div 0.80 = 1\,250$ apparent kw, which results in a single-phase current of $1\,250\,000 \div 10\,000 = 125$ amperes at 10 000 volts. Having the current the resistance and reactance volts are obtained as follows:

*Resistance Volts*—In the table the resistance volts per mile of line for No. 0 wire are 1.04 volts with a current of one ampere. As the assumed distance is ten miles and current has been found to be 125 amperes, the total resistance volts for this distance and current is,—

$1.04 \times 125 \times 10 = 1\,300$ volts, or expressed as percent of delivered volts is 13 percent.

*Reactance Volts*—From the table the reactance volts per mile of line for No. 0 wire with 36 inches between conductors are 1.37 for one ampere at 60 cycles per second and, as the frequency in the example is 25 cycles per second, the reactance volts per mile of line for No. 0 wire is—

$25 \div 60 \times 1.37 = 0.57$ volt. Then the total reactance volts will be—

$0.57 \times 125 \times 10 = 712$ volts, which, expressed as percent of delivered volts is 7.1 percent.

The above percentages of resistance and reactance volts may now be used on the diagram to determine the percent total drop as follows: The power-factor of the load is 80 percent in this example. At this value of power-factor on the diagram follow the vertical line to the intersection with the first circular arc. From this point of intersection lay off to the right horizontally the percent resistance e.m.f. or 13 percent and from the point thus obtained lay off vertically the reactance e.m.f., 7.1 percent. This last point falls on the circular arc which denotes a total drop of 14.5 percent of the delivered e.m.f. Hence the generator or impressed e.m.f. in percent of delivered e.m.f. would be 114.5 percent and the generator voltage would be $10\,000+1\,450=11\,450$ volts.

Example 2 is similar to example 1 except the voltage, kilowatts, and length of circuit are reduced.

Example 3 is similar to example 2 except that the power-factor has been increased.

### EXAMPLE 4—THREE PHASE

In example 4 the number of phases has been changed from single-phase (used in the first three examples) to three phase. As explained in Mr. Mershon's article a three-phase circuit in which the wires are symmetrically placed and all phases are similarly loaded, has the same loss and regulation characteristics as a single-phase circuit using two of the wires and carrying half the load. Therefore, in calculating the three-phase transmission, the calculations are carried out for a single-phase circuit after dividing the apparent kw by two. Hence the apparent kw in this example is $834 \div 2 = 417$ kw and the current in a single-phase circuit having the same characteristics as the three-phase circuit is $417\,000 \div 6\,000 = 69$ amperes. The remaining procedure is the same as for any single-phase circuit.

*Resistance Volts*—The resistance constant for No. 0 wire is 1.04 volts per mile of line per ampere, or the total resistance volts $=1.04 \times 69 \times 8 = 575$ volts or 9.6 percent of the delivered e.m.f.

*Reactance Volts*—The constant for reactance volts per mile of line per ampere at 25 cycles with 36-inch spacing between conductors is 0.57 volt, hence the total reactance volts are $0.57 \times 69 \times 8 = 315$ volts or 5.25 percent of delivered e.m.f.

By laying off on the diagram the resistance volts 9.6 percent horizontally, to the right from the point of intersection of the vertical for 90 percent power-factor with the first circular arc and the re-

## EXAMPLES OF CALCULATIONS OF DROP IN ALTERNATING-CURRENT CIRCUITS

| Given | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E. M. F. at receiving end | 10 000 | 6 000 | 6 000 | 6 000 | 6 000 | 6 000 | 3 000 | 3 000 | 3 000 | 2 000 | 1 000 | 400 | 200 | 100 |
| Kw delivered (Real Power) | 1 000 | 750 | 750 | 750 | 750 | 750 | 200 | 100 | 150 | 500 | 175 | 100 | 25 | 15 |
| Power-Factor | 80 | 80 | 90 | 90 | 85 | 85 | 85 | 85 | 100 | 80 | 80 | 80 | 90 | 90 |
| Number of phases | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 1 | 1 | 3 | 3 | 3 | 3 | 3 |
| Frequency (cycles per sec.) | 25 | 25 | 25 | 25 | 60 | 60 | 60 | 60 | 60 | 60 | 25 | 60 | 60 | 60 |
| Size of wire (B. and S. gauge) | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 00 | 0 | 3 | 3 |
| Distance between wires (inches) | 36 | 36 | 36 | 36 | 36 | 36 | 24 | 24 | 24 | 18 | 18 | 18 | 12 | 12 |
| Length of Circuit { Miles | 10 | 4 | 4 | 8 | 5 | 5 | 3 | 3 | 3 | | | | | |
| Length of Circuit { Feet | | | | | | | | | | 2 500 | 4 000 | 1 000 | 500 | 250 |
| **Deduced Values** | | | | | | | | | | | | | | |
| Apparent Kw | 1 250 | 937 | 834 | 834 | 883 | 883 | 236 | 118 | 150 | 625 | 218 | 118 | 28 | 17 |
| ½ Apparent Kw (for 3 Phase circuit) | | | | 417 | 442 | 442 | 118 | | | 313 | 109 | 59 | 14 | 8.5 |
| Current in amperes | 125 | 156 | 138 | 69 | 74 | 74 | 39 | 39 | 50 | 156 | 109 | 147 | 70 | 85 |
| *Resistance Volts* | | | | | | | | | | | | | | |
| For unit length and one ampere (table) | 1.04 | 1.04 | 1 04 | 1.04 | 1.04 | 1.65 | 1.65 | 1.65 | 1.65 | .248 | .156 | .197 | .394 | .394 |
| For given length and amperes | 1 300 | 649 | 575 | 575 | 385 | 610 | 193 | 193 | 248 | 95 | 68. | 29. | 13.75 | 8.4 |
| Percent of delivered e. m. f. | 13 | 10.8 | 9.6 | 9.6 | 6.4 | 10.1 | 6.4 | 6.4 | 8.3 | 4.75 | 6.8 | 7.25 | 6.9 | 8.4 |
| *Reactance Volts* | | | | | | | | | | | | | | |
| For unit length and given distance between wires, one ampere 60 cycles (table) | 1.37 | 1.37 | 1.37 | 1.37 | 1.37 | 1.43 | 1.33 | 1.33 | 1 33 | .233 | .222 | .228 | .225 | .225 |
| Same for given frequency | 0.57 | 0.57 | 0.57 | 0.57 | 1.37 | 1.43 | 1.33 | 1.33 | 1.33 | .233 | .092 | .228 | .225 | .225 |
| For given distance and amperes | 712 | 357 | 315 | 315 | 507 | 530 | 156 | 156 | 200 | 86 | 40 | 33.5 | 7.9 | 4.78 |
| Percent of delivered e. m. f. | 7.1 | 5.9 | 5.25 | 5.25 | 8.4 | 8.8 | 5.2 | 5.2 | 6 7 | 4.3 | 4.0 | 8.4 | 3.9 | 4.78 |
| **Values to be applied on diagram** | | | | | | | | | | | | | | |
| Power-Factor | 80 | 80 | 90 | 90 | 85 | 85 | 85 | 85 | 100 | 80 | 80 | 80 | 90 | 90 |
| Percent Resistance e. m. f. | 13.0 | 10.8 | 9.6 | 9.6 | 6 4 | 10.1 | 6.4 | 6.4 | 8.3 | 4.75 | 6.8 | 7.25 | 6.9 | 8.4 |
| Percent Reactance e. m. f | 7.1 | 5.9 | 5.25 | 5.25 | 8.4 | 8.8 | 5.2 | 5.2 | 6.7 | 4.3 | 4.0 | 8.4 | 3.9 | 4.78 |
| **Resultant Values** | | | | | | | | | | | | | | |
| Total drop in % of delivered e. m. f. | 14.5 | 11.8 | 11.0 | 11.0 | 10.2 | 13.3 | 8.5 | 8.5 | 8.3 | 6.5 | 7.8 | 10.9 | 8.0 | 9.9 |
| Impressed e. m. f. in percent | 114.5 | 111.8 | 111.0 | 111.0 | 110.2 | 113.3 | 108.5 | 108.5 | 108 3 | 106.5 | 107.8 | 110.9 | 108.0 | 109.9 |
| Impressed e. m. f. in volts | 11 450 | 6 708 | 6 660 | 6 660 | 6 612 | 6 798 | 3 255 | 3 255 | 3 249 | 2 130 | 1 078 | 444 | 216 | 109.9 |

actance volts, vertically as in the previous example, a total drop of 11 percent results. The generator or impressed e.m.f. in percent of delivered e.m.f. would be 111 percent and the generator voltage 6 000+660=6 660 volts.

The remainder of the examples in the table may be worked out in a similar manner by noting in each case the particular set of given conditions. Many of the conditions are the same, except in one or two particulars, as may be easily recognized.

### EXTENSION OF TABLE

The table may be readily extended for wires of larger size and for greater distances between wires. The reactance constant is the same if the diameter of the wire and the distance between wires bear a constant relation. The diameter of wire doubles with a change of six sizes, B. & S. gauge. Hence if the distance is likewise doubled the reactance volts are unchanged.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Thus | No. 8 | wires | 6 | inches | apart | give | 0.220 | and |
| | No. 2 | " | 12 | " | " | " | 0.220 | |
| Also | No. 3 | wires | 18 | inches | apart | give | 0.244 | and |
| | No. 0000 | " | 36 | " | " | " | 0.244 | |
| As | No. 3 | wires | 36 | inches | apart | give | 0.275 | it follows that |
| | No. 0000 | " | 72 | " | " | " | 0.275 | |

In each of the foregoing cases both the diameter and the distance between wires have been doubled.

Examination of the table shows also that when the resistance of the wire is one-fourth as great and the distance is doubled, the reactance volts remain the same. Thus the resistance of the No. 4 is 0.497; one-fourth of this is 0.124, the resistance of No. 000. It will be noted that the reactance volts for No. 4 are the same as those for No. 000 when the latter wires have twice the separation. Likewise a large conductor having one-fourth the resistance of No. 0 will have the same reactance volts if the conductors be separated twice as far apart as the No. 0 wires. The reactance volts of the heavy conductors 72 inches apart will be 0.259, the constant for No. 0 wires 36 inches apart.

A table of resistances and reactances giving a wider range of conductor sizes and distances between conductors, than the accompanying one, was published on page 92 of the February, 1906, issue of the JOURNAL.

# IMPROVEMENTS IN GAS ENGINE IGNITION*

J. R. BIBBINS

IN producer work it is sometimes desirable to change the point of ignition to accommodate different qualities of gas, especially at starting, when the engine is running lightly loaded. With the usual ignition apparatus it is not possible to change the point of ignition while the engine is running and the best point has to be determined by trial when the engine is assembled. This method has proven quite satisfactory when working on natural gas, and in fact it would be better in many ways to so arrange the ignition system that it could not be interfered with on the slightest provocation.

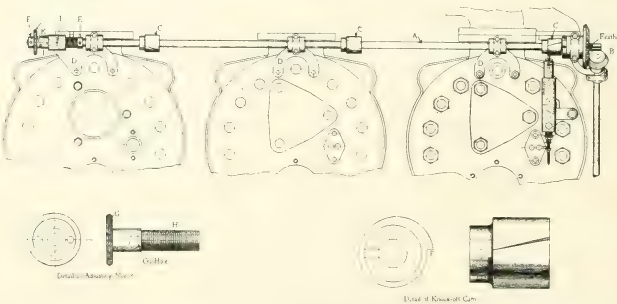


FIG. I—ASSEMBLY PLAN OF IGNITER CAM SHAFT WITH IGNITION CHANGING DEVICE

But the necessities of producer gas working have brought about the change, and an ignition apparatus is necessary which will enable the engineer to advance or retard his ignition point when desirable. Such an apparatus as applied to the Westinghouse gas engine is shown in Fig. 1. This drawing shows that the three igniter cams *C* are mounted on a lay shaft *A* of small diameter supported by brackets *D* positively driven from the main shaft by a train of gears *B* at one end and held between two collars *E* at the other. The knock-off face *E* of each of these cams is not cut straight across as usual, but on a spiral. It is then apparent that if the cam shaft be moved to the right or left, the moment at which the igniter is released will vary according to the shaft displacement. The position of this shaft is controlled by a hand wheel *G* with integral sleeve *H*

*From the *Michigan Technic.*

threaded into the left-hand bracket *D* and held by a lock screw *I*. To change the ignition it is only necessary to rotate the hand wheel a sufficient amount as indicated by a graduated scale *J* with index *K*, which shows precisely the number of degrees which the ignition has been advanced beyond the dead center.

The advantages of this adjustable ignition are apparent from the accompanying curves shown in Figs. 2 and 3, summarizing the data obtained from a series of tests on a 9 by 11 inch two-cylinder gas engine under conditions of constant speed (300 r.p.m.), constant load (70 b.h.p.), constant quality of gas (934 b.t.u. per cubic foot), and variable ignition, (from 0 degree early, i. e., dead center

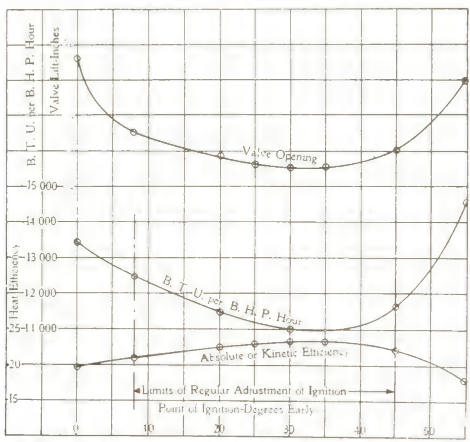


FIG. 2—CURVES SHOWING HOW VALVE OPENING, HEAT UNITS AND THERMAL EFFICIENCY ARE EFFECTED BY VARYING IGNITION POINT

to 55 degrees early). The gas consumption for each test was measured and the heat value of the gas found by a Junker calorimeter. From these observations the b.t.u. consumption per hp-hour was computed at different points of ignition. The curves in Fig. 2 represent heat consumption per b.h.p. hour, the over-all heat efficiency of the engine and the corresponding valve opening, respectively.

From a study of these curves the important effect of proper ignition point is apparent. The efficiency falls off rapidly, if the ignition is either too late or too early. It will be observed that the best point of ignition is shown from 30 to 35 degrees early. This

must not be considered, however, as an arbitrary figure for engines of this size, for the rotative speed, the quality of the gas and other influences combine to change very materially the best point of ignition under other operating conditions. It is the object of this ignition apparatus to make it possible to compensate for these influences at any time.

How easily this is done is shown on the curves. Note that the valve opening corresponds closely with the heat consumption curve. The minimum valve lift corresponds to maximum efficiency, hence

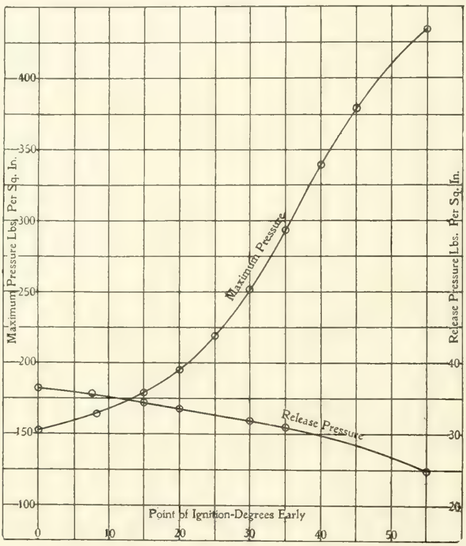


FIG. 3—PRESSURE CURVES SHOWING EFFECT OF VARYING IGNITION POINT

it is only necessary for the operator to adjust the point of ignition for minimum valve lift to secure the maximum efficiency of combustion. It is, of course, assumed that the proper mixture of air and gas has already been obtained.

The eight indicator cards shown in Fig. 4 illustrate in a striking manner the effect of changing ignition point. With ignition at dead center, the combustion line actually retraces along the compression line for a short distance and complete combustion is delayed until

nearly half stroke. On the other hand, with ignition 55 degrees early, the engine works against itself, and the combustion pressures are highly increased without any useful work, the card having no area at this point. Much useful heat in the gas is also lost to the jacket, leaving less heat to be expended in the advantageous parts of the working stroke, as is shown by the low release pressures. The curves in Fig. 3 represent the approximate relation of combustion pressures to ignition. Between 30 and 40 degrees the rate of increase in pressures is the greatest; this is a result quite in harmony with other curves.

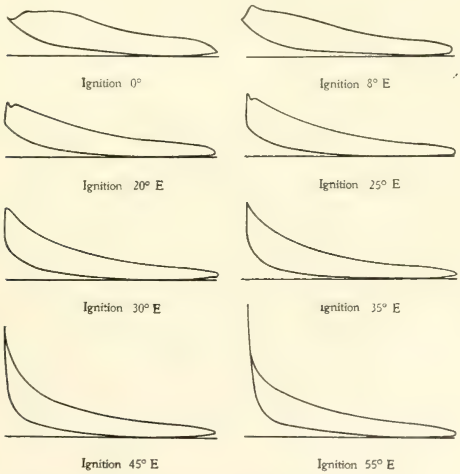


FIG. 4—INDICATOR CARDS SHOWING EFFECT OF VARYING IGNITION POINT

This adjusting device is particularly valuable in assisting the starting of a plant when the producer has been idle for some time or just put in service. At starting, the gas is liable to be sluggish and the compression low owing to the engine running lightly loaded, which requires in both cases an advance of ignition; or in normal running the percentage of hydrogen in the gas may increase greatly from some cause producing abnormally high maximum pressures, which necessitates retarding the ignition point.

# LOYALTY AND RESPONSIBILITY

CHARLES H. PARKHURST, DD.

"Thou hast been faithful over a few things, I will make thee ruler of many things."

IT is a noticeable feature of this parable of the talents that the same words of commendation are spoken to the man who has doubled his two talents as to the man who has doubled his five talents. Approval is calculated purely on the basis of ratio between what a man does and what a man has to do with; in other words, on the basis of his fidelity.

Fidelity is another way of spelling loyalty. Of the two, loyalty is rather the richer word. There is heart in it. Work done with fidelity may be only doggedly done, done strictly as a matter of business as the ticket chopper in a railway station. A man may freeze to his duties, or he may fuse to them. There are several reasons for placing this high estimate on loyalty and many directions in which loyalty may be exercised; for it is like the compass needle which quivers toward the magnetic impulse from whichever one of the three hundred and sixty degrees of the circle the magnetic influence may flow. And one of the effects is that it sets up a current in a man's life, such as coaxes out his powers of action. The difference between people is less in what they are competent to do, than it is in being sufficiently awake to care to do. Loyalty to a specific interest, or purpose, unlocks the somnolent energies of mind and heart in the way that warm airs unlock the ice-barriered rivers. It is customary to speak of developing a man's powers. I am not sure but we might quite as well talk of thawing out his powers.

There is nothing in a university course that will do exactly that thing for a man that is done for him when some great personality, or some vast interest, gets close enough to him to set the inner currents in motion so that, from being a sleepy spectator, he becomes an effectual actor. That suggests the second reason I wanted to mention for placing so high an estimate on loyalty; that it is the quality that is always to be depended upon for getting things done.

God's government of the world, somewhat like human government, may be said to be effected through a policy of commissionerships. I do not believe it is pressing the matter too far to claim that, while He is responsible for everything, He leases a good deal

of his responsibility to subordinates. If it were a matter of accomplishing his purposes in the shortest time, perhaps He would dispense with commissioners, but while delegated authority may embarrass the cause, it is good for the delegates, for it makes any man useful to be used and strong to be leaned upon.

A man sins against himself, against God and against humanity, who does not make himself count for as much to the world as his creator gave him power to count, and who does not let himself be so taken hold of by whatever valiant demand is made upon him as shall qualify him to be in fact all that he is in possibility. And the bearing of this can be traced in every relation of life and in every department of service. A very commonplace illustration of it is afforded in the fact that so many young men of good parts, full of excellent stuff, go through life at a humdrum level, signifying little to themselves and not much to anybody else; never warming to the service devolving upon them to perform; never therefore growing toward the work given to them to do, shriveled by it rather than expanded by it, with no more loyalty to their small responsibility than a draught horse sleepily treading the tow path; with no interest in their work save that it is going to give them a few dollars at the end of the week, wondering why they are not promoted by their employer to a position of larger trust, not realizing that only a growing man is a proper candidate for promotion, and that the mechanical and purely mercenary discharge of duty is never a means of growth and that the perfunctory service they render puts them practically on the same level as a machine.

I am sure I am expressing the sentiment of those of you that are employers, when I say that you are willing enough to let your employes lean on you as fast as they throw themselves into your service in a self-educating way that renders it safe for you to lean a little on them. As a rule people have to earn promotion, and the way to earn it and to acquire positions of larger responsibility is to be so loyal to the responsibility already devolved as shall itself build one up to the proportions of a larger responsibility. To feel the burden of responsibility, to get in under the stress of a responsibility, little, or large, is an immense thing for the man himself.

A few days ago I had a conversation with a man whom I was asking to occupy an official position, and when, in order to induce him to assent to my overture, I said to him that the responsibility involved would be so slight that he would not need to feel the burden of it, he took all the cogency out of my persuasiveness by say-

ing: "I do not feel about the matter in that way. Were I to occupy the position you propose the felt responsibility of it would be a burden upon me all the time, *responsibility means so much to me.*" The obligations upon him are already so numerous that my suit could not be urged farther, but those six words have been running in my mind ever since,—"Responsibility means so much to me." I want to say that I know of nothing better than a realization of how much it ought to denote to any man to come into personal relation with any such interests as shall prompt one to echo the words I have just quoted: "Responsibility means so much to me," and those who are trying to promote any one of the great enterprises looking to the world's betterment, understand with an anxious feeling what all this means.

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# THE HUMAN SIDE OF THE ENGINEERING PROFESSION*

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### FUNDAMENTAL THOUGHT

*Professional usefulness and personal satisfaction depend on the right conception of life and on the degree in which this conception of life is manifested in daily activity.*

### WORK AND CONDUCT

There are three essential requisites for an efficient and successful engineer:

Sound professional knowledge;

Knowledge of business forms and of human relations;

Good and strong character.

*Professional Knowledge*—A man who knows only "how" to do certain things, but does not know "why" they are done so, usually remains in subordinate positions. Get into the habit of analyzing; also, have your knowledge systematized.

In order not to get "rusty" you ought to do some study, or at least some reading outside of your daily routine work. This outside work may be classified, in an ascending scale of difficulty, as follows:

1—Keep notes on your regular work, with sketches, samples of

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*Abstract of an address before the New York Electrical Society.

calculations, etc. On separate notes keep matters of doubt to straighten them out at a future opportunity.

2—Read regularly at least one periodical relating to your specialty, and keep some kind of a general index on at least one subject in which you are particularly interested.

3—Be sure about the fundamental laws, facts, and assumptions on which your branch of engineering is based. If you are but recently from college, you can go over your old books and notes; otherwise read a good modern text-book.

4—Gradually get familiar with more advanced books treating of the various branches of your profession; go from time to time to the public library and see if there is anything new in your specialty.

5—Select some one branch of engineering, if possible somewhat different from that in which you are regularly engaged, and devote time to it. Know more than the next fellow does; it will pay you.

6—Do not miss any chance to make an original investigation; this will develop your thinking, increase your self-confidence and raise your standing in the profession.

7—Inventing is the highest form of the engineering activity; there is no reason why you should not bring some improvement into the work in which you are engaged. Concentrate your mind on one thing, work patiently and persistently, and you will be sure to achieve something that will be new and useful.

*Knowledge of Business Forms and of Men*—You naturally expect some day to occupy a responsible position in your profession. This is impossible without a sound knowledge of established business forms and of human relations in general. Here again there are several stages of study and observation. Take up as many of them as your ambition, time, and ability will allow.

1—Observe the characters of men you are working with; in particular, the influence of their previous experience and education, of their age and temperament, of their views on general life questions, etc.

2—Observe things that make them efficient and happy, or that are impediments in their work; things that they would like to have and the main things that they object to.

3—Observe critically your superiors and their ways of acting towards their chiefs and subordinates. Do this without malice, but rather with a sincere desire to find out the best way of conducting the work, when you shall be called to perform their duties. Make for yourself a clear mental picture of an ideal man in a certain posi-

tion, and try to follow this ideal in your own business life.

4—Observe and read about general business systems adopted in large modern commercial and industrial enterprises; in particular,

(a) Subdivision of the duties of various officers, and their correlation;

(b) Correspondence, accounting, orders, receipts, etc.;

(c) Causes of loss, waste, inefficiency, etc., and possible remedies.

Merely knowing the facts is not sufficient; you must see clearly the necessity for a certain organization. Only then will you find a right place in it for yourself and efficiently discharge your duties.

5—Do not get "rusty" on general life questions; read books on history, economics, philosophy, etc., with the view of finding the underlying facts and motives in human relations. Do not adhere too readily to a traditional school; work out your principles for yourself, and be willing to change them when new evidence is laid before you. A man in a responsible position must be a well educated man; he meets a great many men, and has to face new situations. Therefore he must be well informed on things in general and ought to be able to judge about them.

*Training of the Character*—Engineering and business knowledge are the necessary conditions for usefulness ("success" and usefulness are not always the same), but the proper development of the character is the third necessary condition.

What is the use of having a profound knowledge of engineering, if you have not the necessary perseverance to achieve results; or to have a knowledge of business forms and relations, if your temper is such that nobody cares to be associated with you in business.

Practice daily the qualities of the character that you find esseneial for a good citizen and a good business man.

1—Work patiently on any problem until a result is achieved. If it should be impossible to get satisfactory results, at least make clear to yourself the nature of the hindrances.

2—Be honest in all things; do not be afraid to confess your mistakes or your ignorance. Train your character by doing your work over cheerfully.

3—Keep down your selfish personality and ambition. Do not let them interfere with your business. The highest goal of person-

ality and ambition is to have your part of the work done in the most ideal way.

4—Be generous, polite, and considerate to others; there are no circumstances where you would be justified in breaking this rule. Remain dignified even under unjust reproof.

5—Work with the understanding that your activity of to-day shapes your future. You need not trust to chance; your opportunity will come when you are ready for it.

### UNDERLYING MOTIVES

Some men are happy and efficient in their work without having any clearly defined conceptions of life and its purpose. In a great majority of cases, however, a lack of a workable theory of life brings with a it a decrease in possible efficiency and in personal satisfaction. It is of importance, therefore, to know:

What are the principal limitations and wrong beliefs that are hampering engineers in their work.

How these limitations can be removed by working out a theory of life that gives a general meaning to man's activity.

How an engineer's work is shaped, when his underlying motives are illumined by such a theory of life.

*Usual Limitations* that prevent an engineer from being fully efficient and happy in his work:

1—Belief that he is underpaid; abnormal striving after money.

2—Belief that his efforts are not appreciated by his employer; also that there is no chance for promotion.

3—Lack of knowledge, theoretical or practical; lack of general education; a deficient knowledge of business forms and human relations. This is often accompanied by a belief that he has no time for study; in cases where a man has not exercised his mind for a long time, he has also to contend with his own mental apathy.

4—Deficiencies in character, such as weakness, roughness, egotism, narrowness, pedantry, absent-mindedness, laziness.

5—Lack of enthusiasm due to the absence of a guiding and unifying purpose in life. This is particularly noticeable in very young men who are just beginning to form their own conceptions of life, and in older men who already see the end of their usefulness and cherish no more illusions.

*A Theory of Life*—Each man must work out for himself a practicable theory of life; this will make his acts and words,

thoughts and feelings, harmonious and consistent. The experience of humanity past and present is the material to work on; his reason is called upon to interpret this, and his conscience is the court of final appeal.

The following is an example of such a theory of life:(*)

1—The universe, including man, is governed by an infinite intelligence, which is manifested in man as his conscious life. There is no meaning in a man's life if it be detached from other men's lives. In proportion as he becomes conscious of this one, infinite life, common to all men, his own life becomes reasonable and harmonious, and the fear of poverty, sickness, old age, and death gradually disappears.

2—The highest purpose of life is to work for the realization of the above ideal conditions of life on earth. We do this either by actually removing certain hindrances and fetters (practical work), or by making this great work clearer to others (literary, educational work, preaching, etc.).

3—Once this attitude is understood, the real compensation for the work consists, not in money and notoriety, but in the state of consciousness reached. This is manifested in particular:

(a) In a clear and definite program of life, and a ready answer for all difficulties (doing your best).

(b) In a state of harmony and good fellowship with all men, through the understanding of that life which is common to all.

(c) In a freedom from fear, anger, jealousy, apathy, and other limitations caused by the assumption that life is an accidental chain of phenomena and circumstances.

*Work Illumined by Higher Ideals*—Once he has obtained a workable life-theory, all of the limitations enumerated above, that prevent an engineer from being efficient and satisfied in his work, can be removed by actually applying this theory to his daily work.

1—The belief that he is underpaid or not appreciated enough loses its power; the man works no more for a company or a cor-

*It may seem presumptuous on the part of the writer, who is not a philosopher by trade, to formulate a "theory of life;" this he gives, however, simply in order to illustrate what a practical doctrine of life (not a "canned" religion) may be. For the author personally this doctrine is the truth he believes in and according to which he tries to shape his life; for others it may serve merely as an example. He hopes that by criticising his metaphysics readers may make their own conceptions on the subject clearer to themselves, and in this way be indirectly benefited even by a theory presumably wrong.

poration. He works for his conscience' sake, and finds his true compensation in the results of his work.

2—He is full of desire to do as much as he can, and not as little as he is allowed to. For this reason he wants to know much and to have his knowledge in a practical form, ready for use. He is active and studious all the time, and the expression "mental lethargy" is incomprehensible to him.

3—He frees himself from possible shortcomings in his character by keeping the ideal of perfection continually before his mind's eye. He no longer finds difficulty in handling men and in treating his co-workers and chiefs aright; he has a sincere sympathy for them, tries to help them, and to make their work more pleasant and efficient.

4—He is full of enthusiasm, for he is aware of the infinite importance of his life and work. His work is infinite as is life itself; and each problem solved brings with it a higher and more important problem, brings more truth and light into his consciousness.

## CONCLUSION

1—Make yourself ready for a broader and higher field of activity; then your opportunity will surely come.

2—The true purpose and value of engineering activity lie in providing better and easier ways for satisfying ordinary human needs. This provides more leisure and opens new possibilities for a higher spiritual and intellectual development of humanity.

3—The engineer's personal satisfaction consists in knowing this high purpose of his vocation and in giving his service at a maximum efficiency. The other compensation is a result and not the purpose.

# THE STANDARDIZING LABORATORY—IV

## A NULL METHOD FOR MAGNETIC TESTS

H. B. TAYLOR

ALL who have had occasion to make measurements with a ballistic galvanometer will agree that it is very tedious work and that such tests in the hands of the inexperienced are likely to lead to exceedingly unreliable results. At best the accuracy attainable is far below that reached in other electrical measurements. The measurement of the strength of a magnetic field by means of the deflection produced in a ballistic galvanometer by a search coil cutting the field is still carried on quite extensively in the same way as in the early days of electrical engineering. While the galvanometer itself has been improved in many respects, this method is to be avoided if possible.

Null methods are such a complete success in those measurements involving little energy that it is unnecessary to discuss their advantages in general. In the summer of 1903 a set of apparatus was designed and made in the effort to gain these advantages in certain magnetic tests. During the three and a half years since that time it has been in frequent use and has given satisfactory results.

### PLAN

The general plan of operation is to set up opposing e.m.f.'s simultaneously in the secondary of a standard solenoid and in a search coil which cuts the magnetic field being explored. One terminal of the search coil and of the secondary are joined together. A ballistic galvanometer is connected to their other terminals, forming a closed circuit. The number of turns in the secondary of the solenoid can be adjusted until the opposing impulses are equal as indicated by the absence of deflection in the galvanometer.

The purpose for which the outfit is most used is that of measuring the strength of permanent magnets of the horse shoe type, having narrow air-gaps. The connections for this class of work are shown in Fig. 1. For other similar kinds of testing the only modifications necessary are in the design or arrangement of the search coils and primary switches. Fig. 2 is a view of the apparatus as it is mounted. A Wheatstone bridge and a Carey-Foster bridge with slide-wire, reversing switch, and telescope are also

shown in the cut, as they are permanently mounted on the same table, but they have no connection with the instruments for magnetic tests. The solenoid is at the back of the table. Connections from its secondary are brought out to the plug block at the left of the nearest telescope. The Kelvin balance is used in measuring primary current, which has usually only one value for a series of tests. On the nearest corner of the table is an instrument for testing permanent magnets, with a magnet on top of it in position for test. It will be described later.

SOLENOID

There are eleven separate secondary coils in the solenoid, of 1, 2, 2, 5, 10, 20, 20, 50, 100, 200, and 200 turns respectively. Any coil can be connected in or omitted from the circuit according to the

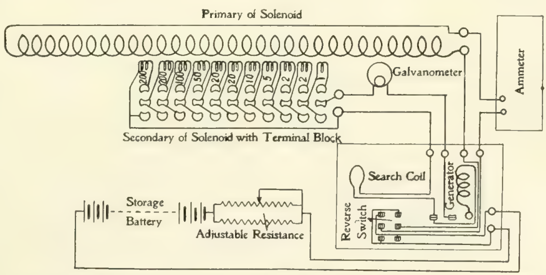


FIG. 1—CONNECTIONS FOR MEASURING THE STRENGTH OF PERMANENT MAGNETS OF THE HORSESHOE TYPE

position of its plug on the terminal block. No coil is ever short-circuited; otherwise the manner of connecting secondary coils in circuit would be the same as for resistance coils in the old "post-office" resistance boxes. Adjustments of the number of turns in circuit are made by trial and error as in adjusting resistances in a bridge rheostat.

In making the solenoid a form of thoroughly seasoned maple 110 cm. long was turned to a uniform diameter of 8.8 cm. At the middle of this form a section was made long enough to hold the 610 secondary turns in one layer and 8.65 cm. in diameter. The secondary winding was put on first and was 8.73 cm. outside diameter, making the mean diameter of turn 8.69 cm. This diameter is obviously too large in proportion to the length of primary to avoid end-

effect, or lack of uniformity of field, due to the brush of magnetic lines emanating from the unbalanced end turns. Considerations of location and convenience outweighed any advantage to be gained by having the results of tests in exactly true magnetic units. The diameter is made large in order that the field enclosed by the secondary may be strong enough to give sensibility without using a large primary current. It is important, however, that the apparatus be constant and that it can be easily duplicated if necessary. The error due to end effect is not excessive. Leads from the secondary coils are brought out through a channel in the wooden form to a terminal block mounted some distance away from the solenoid, as shown in Fig. 2. The primary winding is of copper wire 0.0403 diameter, wound uniformly throughout the length of the wooden form. There are 8.77 turns per cm. of length. By substituting the above figures in the formula for magnetic flux $H = \frac{4 \pi n I A}{10 L}$, neglecting end effect and using as the value of $A$, the area enclosed by a secondary turn, $H$ is found to be 654 maxwells per ampere. This may be called the constant of the solenoid. An even constant would have been more convenient and could have been obtained by using some other diameter. The change of flux due to a reversal of primary current is, of course, double the strength of field. To find the constant for use in measuring the strength of field cut by a given search coil the solenoid constant must be divided by the number of turns in the search coil if the solenoid e.m.f. is to be caused by breaking the primary current, or by half the number of turns in the search coil if the primary current is to be reversed. Readings can then be reduced to maxwells by multiplying the product of this constant and the primary amperes by the number of secondary turns required to neutralize the e.m.f. in the search coil.

### RANGE

The maximum field that could be measured by means of the apparatus is found by multiplying the solenoid constant by twice the maximum primary current and the total number of secondary turns. As 2.5 amperes is the maximum allowable primary current, the field would be $654 \times 5 \times 610$, or nearly 2 000 kilo-maxwells. That is to say, a search coil of a single turn cutting a field of 2 000 kilo-maxwells would have induced in it an instantaneous e.m.f. equal to the sum of the instantaneous e.m.f.'s induced in all of the secondary

coils of the solenoid by reversing a primary current of 2.5 amperes.

No definite limit as to minimum measurable field can be stated. There are several ways of adapting measurements to weaker fields, the principal ones being to reduce the primary current, to simply break it instead of reversing it, or to increase the number of turns in the search coil. Another way is to use a more sensitive galvanometer for weak fields than for strong ones in order that observations involving only a few turns may be more accurate. All ordinary measurements can be made without a change of galvanometer but the other methods enumerated are frequently called into use. It is desirable to have the greater part of the secondary winding in

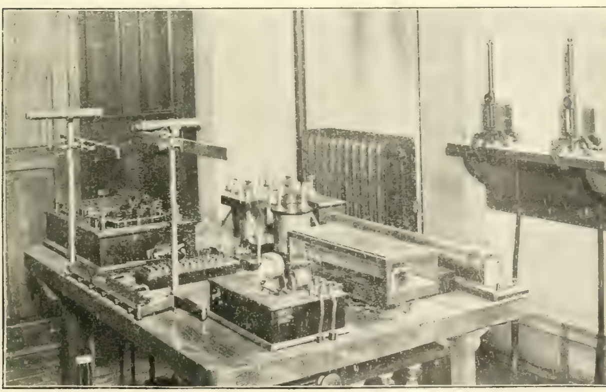

FIG. 2—VIEW OF APPARATUS MOUNTED FOR TEST

circuit in order to have good adjustment. The smallest adjustment being one turn, it will amount to one percent of the total if only 100 turns are in circuit whereas it is 0.2 percent when 500 turns are in. It is also desirable to keep the potential in each part of the galvanometer circuit comparatively high in order that differences which are small in proportion to the total amounts will still be large enough to be shown distinctly by the galvanometer. One of the advantages of this method is that the number of turns in the search coil is not limited by the sensibility of the galvanometer. It is customary to employ potentials either one of which would throw the galvanometer deflection far beyond the scale if unopposed.

## GALVANOMETER STOPPING DEVICE

If it were necessary to wait for the galvanometer to come to a stop without help after each trial adjustment the time consumed would be prohibitive. For the purpose of bringing the galvanometer quickly to rest after a deflection, a small generator is connected through a key to the galvanometer circuit. The key is pivoted at the middle. In its normal position it leaves the galvanometer circuit open. Contact is made on its left side through a switch jaw which holds it in the closed position when placed there. At the other side, contact is made through platinum points which separate when the key is not held down. The connection through the jaw contact leaves the generator out of circuit; that through the platinum points puts it in. The key can be conveniently held in the latter position with the little finger of the right hand while the generator is turned with the thumb and forefinger.

The generator consists of a permanent magnet with a variable air-gap. This air-gap is surrounded by a coil of wire and is shown diagrammatically in Fig. 3. Fig. 2 also gives a view of one mounted on the magnet-testing box. The width of the air-gap is varied by means of a knurled-head screw. As the gap widens the magnetic field scatters out through the surrounding coil, setting up an e.m.f. in a certain direction. Closing the gap concentrates the field, causing an e.m.f. in the opposite direction.

The highest rate of change of magnetic flux for a given speed of screw occurs when the gap is narrow. A quick half-turn of the knob in that position will turn the moving element of a galvanometer of average sensibility through a complete revolution. With wider air-gaps the rate of change is lower, allowing accurate control over small deflections. This instrument has proved to be very effective. No skill is required to operate it, and the galvanometer can be brought from extreme swing to complete rest in a few seconds. Beside being small and convenient as compared with the damping method employing a battery and resistances, it has a distinct advantage in the time required to bring the galvanometer to rest.

## TESTING PERMANENT MAGNETS

Measurements of the strengths of permanent magnets furnish good examples of the class of work for which this method was devised. It is obviously not suitable for a shop method of testing

magnets, but rather for checking the permanence of standards used in shop methods. The instrument shown on a corner of the table in Fig. 2 was made for use exclusively in such work. An idea of the scheme of internal construction will be obtained by reference to the diagram of connections in Fig. 1. A brass rod runs lengthwise inside the box, near the front. It is pivoted to turn through an angle of about 30 degrees. To it are attached a reversing switch and a hard rubber lever which carries a circular search coil at one end and projects through the box at the other. A bronze spring of adjustable tension at the end of the box connects with the brass rod. Its tendency is to turn the rod in a direction which places the search coil below the surface of the box and closes the "reverse" side of the switch contacts. By pressing the lever which extends through the box, the position of the search coil can be raised so that slightly more than a semi-circle of it projects through a slot in the top. At the same time the switch connections are changed to "direct." A spring catch holds the lever in the latter position until a button just below it is pressed. The coil then drops below the surface and the switch reverses at the same moment. The magnets to be tested are of a variety of forms and sizes but all have air-gaps narrow enough to permit a comparatively small coil to encircle the entire field. They are placed on top of the box in such a position that the search coil, when raised, will encircle the field.

For convenience, the battery is always connected in the same way, making the throw of the galvanometer due to the solenoid always in the same direction. This is tested by plugging in only one or two turns of the secondary and breaking the primary current. To test the direction of throw due to the magnet, the search coil is dropped from a position in which it encloses only a small part of the magnet's field while the solenoid primary is disconnected. If the throw is in the same direction as that due to the solenoid the magnet must be turned around.

Approximate values, only, of primary current are observed until the adjustment of secondary turns is nearly correct. Greater care as to all details is exercised when the final readings are taken.

### ACCURACY AND TIME

Magnets of such a shape that they can be quickly placed in the proper position with relation to the search coil and which do not vary more than 150 percent from minimum to maximum strength can be tested at the rate of about twenty per hour. At that rate

there is no difficulty in duplicating results repeatedly within 0.5 percent. By taking more time and checking each set of readings the results are reliable within 0.2 percent as comparisons. The actual values obtained in magnetic units are not quite as definite as the comparative strengths, although there must naturally be a certain ratio which, once known, would make absolute values as definite as the comparative ones. A slight uncertainty as to absolute values arises as the result of several items. The end effect of the solenoid has already been mentioned; iron permanent fixtures in the neighborhood of the solenoid may reduce the reluctance of path of its magnetic field somewhat below what it would be if perfectly isolated; the momentary e.m.f.'s in the two sides of the galvanometer circuit, having different characteristics, may not indicate exact equality of field when they neutralize each other. Moreover, a sensitive galvanometer can seldom be made to indicate exact equality of impulses by standing perfectly still. It will usually start quickly in one direction, stop suddenly, and swing slowly back, when the nearest approach to a balance has been reached. To make the swing take one direction only, (the outer limits of uncertainty), requires a change of from 0.3 percent each way. It has been necessary on that account to adopt a conventional "zero" deflection. Different galvanometers do not always give the same results. Although some agree perfectly with each other, and the difference is almost always below 0.5 percent, a maximum difference as high as one percent has been found between results obtained with two galvanometers of widely different characteristics. Very heavy galvanometer coils can be made to indicate a perfect balance, but they are less sensitive, so that nothing is gained by using them.

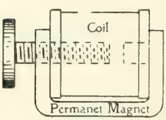

FIG 3—GENERATOR

In comparing the null method with deflection methods it should not be forgotten that all of the uncertainties as to absolute values enumerated above apply equally to a deflection method, in which the galvanometer is calibrated by means of a standard solenoid and used in measuring the impulse received from a search coil. Ballistic galvanometer theory is based on the assumption that the total impulse is delivered from the source to the galvanometer before any motion has taken place. Ordinarily there is no way of determining whether this is the case. With the null method, if the impulse is too slow to give reliable results the fact is at once evident. Probably an arrangement for breaking the solenoid circuit through a resistance

could be made to balance a slow field discharge.

MISCELLANEOUS MAGNETIC TESTS

A variety of requirements in magnetic work may be met by adapting the design of search coil and primary switch to suit the conditions. Among the uses to which the apparatus has been put are: measurement of hysteresis of hard steel bars; distribution of field in large electromagnets; total field cut by the coil of a direct-current instrument in swinging throughout its working range.

The auxiliary apparatus used in measuring hysteresis consists of a magnetizing coil having a hollow core large enough to admit the

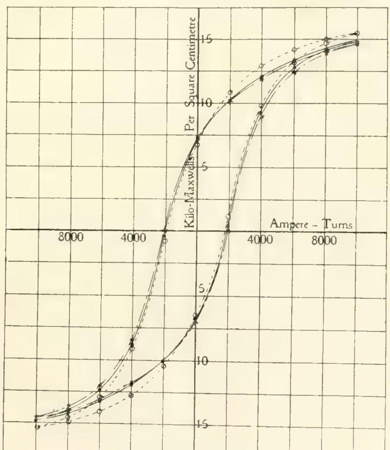


FIG. 4—HYSTERESIS LOOPS OF THREE PIECES OF HARD STEEL, SHOWING EFFECT OF DIFFERENT PROCESSES IN TEMPERING

sample bar and leave room for a search coil to slip freely over it between the coil and the sample. The bars are 12 inches long and from 0.25×0.75 inches to 0.5×1.25 inches in cross-section. They are held in a vertical position so that the search coil will fall by gravity from its initial position at the middle of the bar to a position about 4.5 inches below the end. Connections from the search coil are brought out through straight brass rods 0.1 inch in diameter with flexible leads connected to them at the top. These rods serve also

as a support for the search coil. As they are fastened at opposite ends of the coil frame for the sake of mechanical rigidity, the coil must always have an odd half-turn to make connection. From 4.5 to 15.5 turns in the coil are sufficient for measurements over a wide range of strengths. The magnetizing current is held constant at each step while the strength of the magnet is being measured. In falling the search coil support automatically opens the primary circuit of the solenoid just before the coil passes over the end of the bar. Results of tests are plotted in terms of kilo-maxwells per square centimeter and ampere-turns in the magnetizing coil. Knowing the dimensions of coil and mounting, conditions could be duplicated if necessary, even if the magnetizing coil in use at present were destroyed. The relative positions of coil and magnet and the shape of the magnetic circuit do not, however, lend themselves readily to calculations in terms of magnetizing force.

Fig. 4 is an example of the application of the apparatus as an indicator of coercive force in magnet steel. Three samples were cut from the same bar and tempered in different ways without being subjected to any other treatment. The three curves of Fig. 4 are their hysteresis loops. Points on the curves can be located quite definitely, as the available energy in each side of the galvanometer circuit is high, making the galvanometer sensitive to the smallest adjustments. Slight deviations from a uniform curve are noticeable when a great number of points are located, but there is seldom any difficulty in making a smooth curve pass through all of the points when taken at the intervals shown in the figure. It is believed that the discrepancies are less than would occur if the ordinary ballistic method were used. Certainly the actual performance of the work does not require more time, nor as much skill.

For investigating the distribution of field between the poles of a large but weak electro-magnet, a search coil having fifty turns of fine wire and a cross-section of four sq. cm. was provided and so mounted that it could be quickly turned over while in any part of the field. Its support was arranged to be clamped in a definite position, to allow of repeated trials. The same spring that turned the coil through the 180 degree angle broke the primary circuit of the solenoid. Nothing elaborate in auxiliary equipment was used; it consisted chiefly of a wooden clamp, a hand-made search coil and a rubber band. With this apparatus measurements were made which gave the definite information required.

# EXPERIENCE ON THE ROAD

### A FEW "DONT'S"—SOME POINTERS FOR YOUNG ERECTION ENGINEERS

H. GILLIAM

SEVERAL years ago, while in charge of a district office, the writer had occasion to use the services of some engineers just off the apprentice course. These men, after reporting, were assigned to work on different installations. Through ignorance or inexperience, the result of their work was far from satisfactory, and the district engineer was kept in hot water most of the time, due to their mistakes.

These men were anxious to succeed and came to the district engineer for advice, and asked that he give them a few rules to guide their work. The mistakes of each in turn were taken up and a list handed them for their guidance. It may be added that all mended their ways, and are now holding responsible positions in various parts of the country.

The rules which guided them are the following:

I. Don't tell everything you know the first day you arrive to install apparatus. You may want to carry on a conversation the other days you are on the job.

II. Don't promise things that are not in the contract. The factory has a way of turning down such promises which makes you feel badly.

III. Don't think you know it all just because you are from a big company. There are a few smart men not working for your company.

IV. Don't write letters to the local company; the factory has men who are paid to do this work of writing letters.

V. Don't say any more than you have to. By keeping your mouth shut you are likely to get the reputation of being a smart fellow.

VI. Don't think because a man has worked all his life for a local company and you have just arrived, that he cannot give you a pointer or so. The dumbest people sometimes know a thing or two.

VII. Don't take any one's word for everything being all right, but see for yourself. Trouble has a way of developing when least expected.

VIII. Don't forget what company you are working for, although the superintendent for the local company may say that the

man before you would do "so and so." If you do not stick to the contract your company may have a man who can fill your place.

IX. Don't forget that all of us make mistakes sometimes. It does not follow from this that you must make mistakes all the time.

X. Don't think that just because you have had the students' course you know more than the old road men. Some of the old road men have forgotten more than you ever knew.

XI. Don't forget that the officials of your company have their eyes on you. Sometimes a position opens up and if you had worked hard you might have gotten it.

XII. Don't think when you come in from a job that you are expected to hold the office furniture down. If no work is at hand look up some. Get busy.

## REBUILDING COMMUTATORS

H. V. RUGG

TO install new commutator mica, clamp rings are not always available, and, in some cases, the V-rings are in one piece, making it impossible to remove sections of the commutator without disturbing the balance.

In the following instance, it was not desirable to remove the armature from the bearings, or to disturb the armature windings, or that the commutator be removed bodily from its place. A wooden V-ring was made of the same size and shape as the metal V-ring in the commutator, and cut into sections. A band was then put around the commutator until the V-ring was removed and replaced by the sectional wooden V-ring. This band was then removed and, by taking off one section of the wooden V-ring at a time, it was an easy matter to remove a section of the commutator bars and reinsulate them, without disturbing the remainder of the commutator. This procedure was followed until the entire commutator was reinsulated, when the permanent V-ring was again put in place.

As no clamp ring was available for tightening the commutator, a flexible wire rope was procured and wrapped around the commutator several times. One end of this rope was fastened to the floor and the other to an overhead crane, and when the rope was tightened by the crane an even pressure was exerted all around the commutator. In this way the commutator was tightened and shaped up

after which the armature winding was resoldered to the commutator and the commutator turned off.

The above method resulted in a considerable saving of time and labor, and in this instance was very satisfactory.

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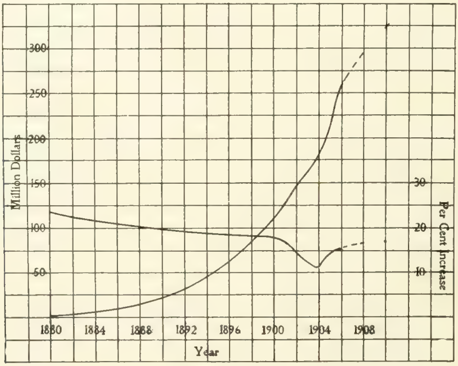
"An interesting statement in a recent address by James M. Dodge, then president of the American Society of Mechanical Engineers, which is confirmed by the experience of our own graduates, reveals the fact that the average annual salary of the technical trained man is over $2 150, and for the non-technical, but trade trained man, $790, so that the gain in average annual income due to a technical training is over $1 360. This amount capitalized at four per cent. gives to a man receiving a technical training a potential increase in value of $34 000. There are over one thousand living graduates of the institute, to make no mention of an equal number who have spent more or less time at the institute, but who have not taken a degree, so that at the lowest computation the work of the institute since its incorporation, if measured in dollars and cents alone, would represent a capitalization of over $34 000 000. This represents merely a capitalization of the increased earning power of our graduates and takes no account of the enterprises which they have developed and which they direct, which would easily make the pecuniary measure of the contribution of our graduates to the world's assets a sum not less than $50 000 000." Commencement address, Technical Education in Relation to Industrial Development, June 14, 1906, at the Worcester Polytechnic Institute, by Charles G. Washburn, president of the corporation. *Science,* July 27, 1906.

# PROGRESS OF ELECTRICAL PRODUCTION

FOR a number of years the *Electrical World* has published, at the beginning of each year, an editorial giving estimates and statistics showing the production of electrical apparatus for the preceding year or years. These figures have been checked by census returns and other reliable sources from time to time and are apparently consistent and very conservative. An investigation of these returns for the various years beginning with 1880 has resulted in the production of the curves shown in Fig. 1, which give in graphical form the results of the tabulation of figures for the years from 1880 to date. One curve shows the growth in production from year




CURVES SHOWING INCREASE IN ELECTRICAL PRODUCTION IN THE UNITED STATES

to year and the other the yearly percentage of increase. Commercial activity in the electrical field has evidently advanced each year. The lowest percentage of increase was eleven percent. For 1906 it was fifteen percent. In the earlier years the figures did not cover such a variety of product as more recently and probably the figures were more in the nature of general estimates than at present. The dotted extensions of the curve of production is apparently conservative and indicates a production of the value of $275,000,000 for 1907.

The continued growth indicated by these curves makes it evident that the "knee" of the curve is not yet in sight and that there will be a still greater total production for years to come.

THE

# ELECTRIC JOURNAL

VOL. IV. APRIL, 1907 NO. 4.

**Railway Signal Engineering**

The articles on interlocking which the JOURNAL is publishing give the reader a knowledge of the fundamentals of a somewhat intricate art. The writers are men of special information in their subjects, and they have learned thoroughness through years of contention with actual facts, so that what they have written is beyond any suspicion of superficiality. In fact, the article on "Electric Interlocking" is by the father of that special application of electricity to engineering, for Mr. Taylor was the first man to invent and design a scheme of electric interlocking which was commercially successful. The father of electro-pneumatic interlocking is Mr. Westinghouse, and unfortunately he is too much occupied to write. The father of mechanical interlocking must be dead, and it would be dangerous and unprofitable to try to name him.

The intelligent engineer who looks these articles over will be struck by the amount of high-class engineering that has gone into interlocking; then as he reflects he will realize that these articles, excellent as they are, have only started him in a new field of engineering. They have told him how certain things may be done, but they have not told him what things are to be done, or why. If he tries to imagine the conditions at a great terminal he will begin to understand that the application of the apparatus and methods that have been described is a development of engineering which, perhaps, he has not heretofore suspected; for signal engineers have never done their duty in contributing to the literature of the profession.

If interlocking and block signaling are looked at merely as measures of safety, the matter is comparatively simple. The engineer still has to use ingenuity and knowledge and skill of a high order, but he does not have to employ the higher powers of judgment and analysis and constructive imagination in such degree as to put his work in the first rank of engineering. This narrow view,

which is taken by many operating officers of railroads, and even by many signal engineers, is not unnatural, for the responsibility for safety is a tremendous one. But a broader view takes cognizance of increased efficiency as well as of greater safety. Unless the signal engineer keeps always before him the purpose of getting more returns out of a unit of track, as well as the purpose of making operation safer, he must be content to remain in a subordinate professional place; for the higher engineering is not merely protective engineering, but productive engineering. H. G. Prout

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**Drop in Alternating-Current Circuits**

Ohm's law has been practically applied for so long a period by users of electricity as to have become recognized by even the lay fraternity as a synonym for the fundamental principles of the art. E=CR for direct current and the problem is solved. There is, however, in connection with alternating current "something different" and the manipulation of more or less involved formulae leaves in the mind a feeling of insecurity in results which is not present in the case of direct-current calculations.

It was to simplify the solution of this problem that Mr. Mershon worked out his method which was reproduced in the March issue of the Journal. The article by Messrs. Scott and Fowler in the present issue is productive of two results:—A further recognition of the elasticity of the time honored method of Mr. Mershon and admiration for a most ingenius and practical new short cut for securing the old results. Much of the success of the old diagram lay in clearness and simplicity, and the tables of the present article further this simplicity by reducing the number of steps necessary in the application of the method to a given set of conditions. The illustrative diagrams of the present article make an illuminating presentation of the data which is necessary and the steps to be taken in determining the drop by each of the two methods.

The usefulness and value of this information cannot be more forcibly shown than by citing a recent instance which came to notice. For the operation of a 150 hp motor, power was transmitted 2 000 feet over two independent circuits, in parallel, consisting of one No. 00 and one No. 0 line. The drop in voltage was excessive and the remedy first suggested was the addition of a third circuit of No. 0 wire in parallel with the first two, the three circuits being arranged independently so as to secure the least reactance. This

would have meant an increase in the copper of forty-five percent and reduced the total drop from over twenty-five percent to fifteen percent. A further investigation showed that if the No. 00 circuit be replaced by two circuits each of No. 2 wire, suitably arranged in connection with the No. 0 circuit, the weight of copper would be kept the same and the total drop reduced to eighteen and one-half percent. From this it will be seen that the additional forty-five percent in weight of copper reduced the drop only three and one-half percent over a rearrangement of the same weight.

This is suggestive of the possibilities of the tables in the present issue, for, while the instance given contemplated the use of multi-circuits, it is equally true that doubling the cross-section of copper in a single circuit reduces the total drop in many cases by a very small proportion as compared with the same result in a direct-current circuit. This is particularly true of circuits of high frequency and low power-factor. The tables in the present issue are a step forward in making easier the calculation of drop in alternating-current circuits and will be very gratefully welcomed.

A. M. Dudley

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**Unequal Distribution of Potential**

The contribution by Mr. Ingram in this issue of the Journal discloses some very peculiar effects found on multi-gap lightning arresters caused by the unequal distribution of potential across the various gaps. The phenomena described explain the eratic action of such arresters when installed under conditions apparently identical with those in which the action had been entirely different. A remedy is also offered which suppresses these troublesome characteristics, and permits the voltage at which a series of gaps in an arrester will break down to be determined accurately for not only one condition, but for all reasonable conditions.

It is not obvious, ordinarily, that a series of small gaps will act differently from one large gap. The mind acquires the habit of thinking of all materials as either conductors or non-conductors, and among the latter is classed the air. The incorrect idea is also acquired that potential is something present in a conductor and having no influence on space around it. In reality the air breaks down and becomes conducting when the potential stress over a given linear dimension becomes sufficiently great. Also, potential due to a charge on a body pervades all space but changes in value ac-

cording to laws and equations determined by the shape of the charged body. The rate of change of potential or the slope of the curve of potential, at a given point determines the stress at that point.

As indicated in Mr. Ingram's article, the potential stress over the various parts of a series of gaps is not determined alone by the difference of potential of the two ends of the series. In reality the potential of all the surrounding objects has a marked effect also and may easily produce a condition in which a large part of the stress between the two ends of the gap series may appear over a comparatively small part of the gaps. The remedy suggested is to bring into close proximity to the gaps another object having a known potential to counteract the unfavorable effect of the other but perhaps necessary objects such as walls, barriers, etc.

These characteristics of potential distribution are not confined to lightning arresters, but may well be borne in mind wherever conditions of great potential stress are met with.

R. P. Jackson

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**The Engineer of the Twentieth Century**

One naturally has some misgivings when he reads over what he wrote years before, particularly if it happens to deal with the future. His point of view may have changed or circumstances may have taken place which prove his former views or predictions to have been incorrect.

A few days ago I looked through one of my productions of several years ago. In it I had put certain thoughts and conclusions which were either comparatively new to me or at least had not until recently been fully appreciated. During the preceding year, as president of The Engineers' Society of Western Pennsylvania, as an active factor in the organization of The Electric Club and as president of the American Institute of Electrical Engineers, I had given the problem of engineers and engineering organizations considerable thought and study. I had come to appreciate the needs and had sought ways and means for the development of these organizations. As the consequence, the real position of the engineer in his relations to society in general and the relations between engineers and engineering societies presented themselves to my mind in a new light.

When I came to write the address to which I have already referred, the paragraphs followed one another in a sort of logical

sequence. The suggestion of co-operation among engineering societies and the vision of a "Capitol of American Engineering" followed from what preceded, not merely as a happy sentimental climax, but as their logical outcome.

Others have told me that at the time they thought me quite visionary. In fact, I rather thought so myself and I must confess that it required some courage to present in a serious way so obviously impossible a project as a magnificent building as the home of the great engineering societies. Nevertheless, "the impossible has become the commonplace." It was just ten weeks later that Mr. Carnegie wrote the letter which made it a reality, and the Engineering Societies' Building erected at a cost of one million fifty thousand dollars, on land which cost five hundred twenty thousand dollars, is now ready for the dedication on April 16th. At about the same time the new Engineers' Club building—adjacent to and erected in conjunction with the societies' building under Mr. Carnegie's gift of a million and a half—will be completed.

The views with regard to the relations of engineers among themselves and to society, which found expression in "The Engineer of the Twentieth Century" a little over four years ago have lost none of their importance and significance in the rapidly following events of the intervening years. A much broader generalization with regard to these relations is given by Mr. George S. Morrison in "The New Epoch," a book of remarkable insight and far-reaching consequences which appeared the following year.

The address, which is reprinted in this issue of the JOURNAL, is one of peculiar interest to me because its preparation crystallized in my mind the ideals which have been the impelling force in my relations to the great enterprise which is now at its completion and which is to be the physical basis of a new and wider activity and influence among engineering societies. CHAS. F. SCOTT

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**Series Transformers**

Two very important points mentioned in Mr. Taylor's article on "Measurements Involving the Use of Series Transformers" in this issue of the JOURNAL, are that the current ratio is affected by the impedance of the secondary circuit and that this variation in ratio changes with the current, being less at full-load and increasing as the current decreases. The variation in current ratio is due to the fact that the primary ampere-turns must be greater than the secondary ampere-turns by just a sufficient amount to make up for the

magnetizing component for the core and for leakage due to cross-magnetism between the primary and secondary coils. Increasing the secondary impedance necessitates an increase in the flux set up in the core to induce additional voltage in the secondary coil, and this, consequently, requires an increase in the magnetizing component of the primary current. In order to reduce the variation in ratio to a minimum the flux density in the core is made very low, and at these low densities the magnetizing current is not proportional to the flux. In other words, the iron is worked on the steep part of the magnetization curve. When the current is less than full-load the flux in the core is proportionately less, but the magnetizing component of the primary current is not proportionately less but a greater percent.

These variations make it essential that for accurate measurements the transformer be operated at approximately full-load current, and that for a series of measurements using one transformer the impedance of the secondary be kept constant. It is sometimes desirable, especially in switchboard work on high tension circuits, to employ one series transformer to operate two or three instruments. In connecting up several instruments in this way it must be remembered that each additional instrument increases the ratio error and that if any of the instruments have a particularly high impedance the readings of the whole set of instruments will be affected. If accurate measurements involving the use of switchboard instruments are to be made, as in the testing of a power station, the safest method, where several instruments are on one circuit, would be to short-circuit all the instruments but one in taking readings, or to calibrate the instruments and transformer together.

Another source of error which should be considered when extreme accuracy is desired in wattmeter measurements, made with a series transformer, is the phase displacement between primary and secondary currents. This displacement is so small in ordinary transformers as to produce no appreciable error in wattmeter readings taken at one hundred percent power-factor, but may noticeably affect the measurements on circuits of lower power-factor. A phase displacement of one degree will introduce an error of approximately one and one-fourth percent. The best way to correct readings for this error is to have the wattmeter and transformer calibrated together on a circuit of the same power-factor as the circuit to be measured.

While ordinary series transformers have sufficient capacity to carry two or three indicating instruments without serious error, it is

not considered satisfactory to operate integrating instruments in the same secondary circuit with other instruments, and they are usually operated from separate transformers or from an independent secondary of a double circuit transformer. Transformers of this kind are now made having one primary and two secondary windings, each secondary being on an independent core so that the current ratio of one secondary is absolutely unaffected by the load on the other secondary.

W. H. Thompson

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**The Proposed A. I. E. E. Constitution**

The rapid growth of the Institute naturally calls for changes from time to time in its organization and methods. The changes incorporated in the proposed constitution which has just been issued to the members for letter ballot, deal mainly with matters of routine.

Several of the proposed changes are of greater significance. In other societies it is customary to admit to full membership competent engineers without restriction as to the branch of engineering in which they are proficient. In the electrical society, however, a full member must at present be a professional electrical engineer. The modification now proposed takes a middle ground by which a duly qualified engineer in an allied branch of engineering and who has a certain experience and competency as an electrical engineer may become a full member.

A further modification is the requirement that an associate shall be twenty-one years of age. Personally, I regard these changes as acceptable but quite inadequate, as the number of grades of membership should be increased. Seven-eighths of the membership are associates and includes three general groups of men: First, those who are professional electrical engineers, but who are not qualified by age or experience to be full members; second, a large class of those whose work is allied or associated with electricity, who are connected with the management or commercial phases of electrical work, or who are in allied industries or occupations which utilize electricity; and, third, young men who are students or apprentices, whose connection with the Institute is largely of an educational nature, and who should not properly be classed with professional electrical engineers. The Institute should have all these classes associated with it, but it is neither logical nor fair to group them all in one class. My criticism on the proposed constitution is, therefore, that it does not go far enough, although it is right as far as it goes.

Additional standing committees are proposed—Sections, Standards, Code and Law Committees. These are important additions and give constitutional recognition to lines of activity which have grown up during the past few years. The specified duties of the Standards Committee are limited to matters relating to units and standards. As a matter of fact, the work of this committee is much broader, including methods of test and engineering practice, as well as definitions and classification. The Sections Committee is to have general supervision of the sections and branches of the Institute. This work is laid out on fairly broad lines and contemplates a closer organic connection between local organizations and the Institute management in the growth of this important and vital department of its activity.

The section with regard to amendments provides that a favorable vote of seventy-five percent in a total vote of not less than thirty percent of the membership shall be required for the adoption of amendments. At present, an affirmative vote of a majority is necessary. While it should not be made too easy to change a constitution, yet it must be recognized that it is very difficult to get a full vote from the Institute membership, which is widely scattered and contains many members who are quite passive in their relations and pay no attention to circular letters or ballots. Undoubtedly the majority of the active members of the Institute are in the thirty percent who would make response to a letter ballot. Moreover, the ballot will be open to all members and those who fail to respond should not prevent the seventy-five percent of those who do respond from accomplishing their purpose.

In general, therefore, the proposed changes are either of a routine nature, or are conservative in character, or give recognition to the growing activities of the Institute. The changes proposed by the Institute officers, which deal mainly with the methods they use in conducting the work of the organization, should be endorsed as a matter of courtesy by every member, unless he has a very good reason for not doing so.

Chas. F. Scott

# CIRCULATING CURRENTS IN THREE-PHASE GENERATORS

A. G. GRIER

Consulting Engineer, Montreal, Canada

IN an ordinary single-phase alternating-current circuit the wave shape may be sinusoidal or it may be the resultant of a fundamental sine wave and several component harmonics or sine waves having frequencies of respectively two, three, four, five, etc. times that of the fundamental. If the half waves are symmetrical, then there are no even harmonics, but only the third, fifth, seventh, etc., are possible.

In a three-phase system (employing no neutral or common return) the wave form is further limited, in that the third harmonic and others which are multiples of three cannot exist. In a three-phase system, therefore, in which the wave shape is symmetrical, no even harmonics and no third harmonics or multiples thereof can exist. The possible harmonics, therefore, are the fifth, seventh, eleventh, thirteenth, etc.

A three-phase generator usually has three windings giving electro-motive forces displaced 120 degrees. These three individual electro-motive forces may be considered as single-phase electro-motive forces and they may be either of the simple sine form or there may be harmonics including the third harmonic. These three windings, however, are usually connected in delta or in star for supplying a three-phase system. When the star connection is used, it happens that the third harmonics which exist in the two windings which are connected in series between any pair of the three-phase terminals are in opposition, having equal and opposite values, so that they neutralize one another and no third harmonic appears in the electro-motive force measured between the terminals. If, on the other hand, the three windings are connected in delta, the third harmonics in the three windings are in the same direction, so that they send a current through the three armature windings in series. Thus, the third harmonic is short-circuited in the armature and does not appear in the electro-motive forces measured between the terminals.

The conditions may be better appreciated by referring to a diagram. In Fig. 1, $A_1$ is shown with a harmonic marked $A_3$. In Fig. 2, the curve $B_1$, is displaced 120 degrees from $A_1$, in Fig. 1.

NOTE.—The writer's thanks are due to Mr. E. Heitmann for suggestions made.

In the curve $B_3$ is the third harmonic. In Fig. 3, $C_1$ is displaced 120 degrees from $B_1$, and $C_3$ is the third harmonic. In Fig. 4, the

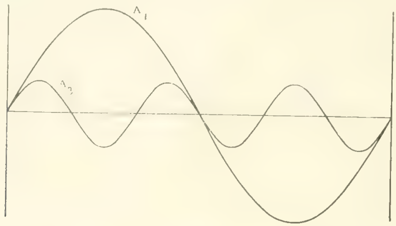



FIG. 1

first three figures are superposed. It may be noted that $A_1$, $B_1$, and $C_1$, have the proper 120-degree displacement, as in the three-phase

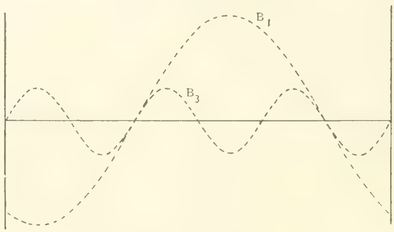



FIG. 2

system. The third harmonic curves for each of the three fundamentals occupy the same position. In other words, the three are

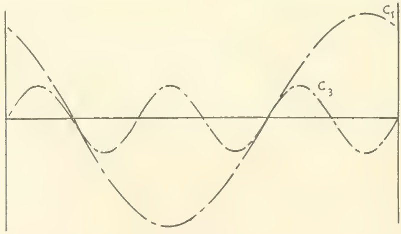



FIG. 3

coincident. At the instant at which $A_1$, has its maximum value, $B_1$, and $C_1$, are opposed in sign and of half the value of $A_1$. In other

words, $B_1$ and $C_1$ both oppose $A_1$ and have the same numerical value. If, therefore, the three be in one circuit, their sum, being zero, will give no resultant. Likewise, at all other instants the value of one of the fundamental waves is exactly opposed by the sum of the other two. If, therefore, the three be connected together in

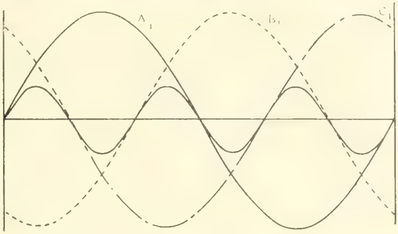



FIG. 4

series, as in a delta connection, there will be a zero resultant effect within the closed circuit.

The conditions are different, however, with regard to the third harmonic. At each instant the third harmonics of all waves are in the same direction. Consequently, in a closed or delta arrangement the three act together and will produce current flowing in this closed circuit.

Fig. 5 is constructed in a manner similar to Fig. 4, except that

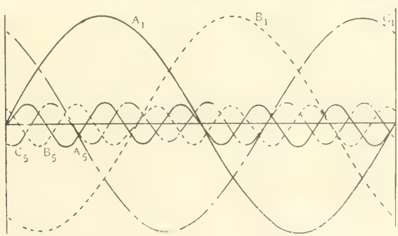



FIG. 5

the fifth harmonics instead of the third are shown. It may be noted that the different fifth harmonics are not coincident, but are symmetrically displaced. The algebraic sum of the three harmonics at any instant is zero, and it may be further noted that they produce a rotating field, but in a direction reverse to that produced by the fundamental.

In the case of a star-connected generator at the instant phase $B_1$ in Fig. 4 is at its maximum value, the phases $A_1$ and $C_1$ are each at half the value of $B_1$, but both in the opposite direction to $B_1$, so that for a star connection the phases should be connected as in Fig. 6 to a neutral point allowing of the flow of currents as indicated, that is if current in phase $B_1$ flows towards the neutral, the currents in

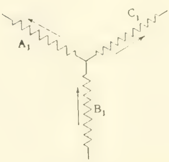



FIG. 6

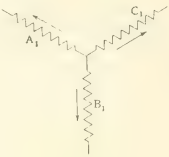



FIG. 7

phase $A_1$ and $C_1$ should flow away from the neutral. Fig. 4 also shows that at the same instant (when $B_1$ is a maximum) each of the third harmonics is a maximum and in the same direction as phase $A_1$ and phase $C_1$, but in the reverse direction to phase $B_1$ so that the direction of the third harmonic e.m.f.'s will be as in Fig. 7. That is, the e.m.f.'s are all in a direction away from the neutral point and since they are all in phase their effect in producing current in the external circuit will be zero. From this it follows that with a three-wire external circuit and with the neutral point of the generator not grounded, although the e.m.f. wave in each leg can contain any or all of the higher harmonics, the e.m.f. wave across

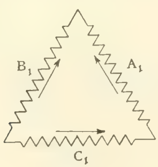



FIG. 8

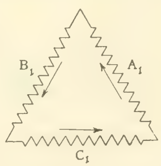


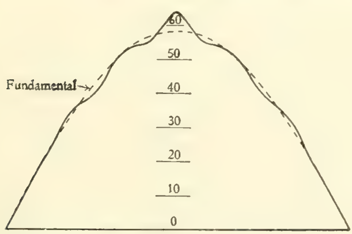

FIG. 9

any two legs cannot contain the third harmonic or multiples thereof, or, in other words, harmonics that are in phase with one another.

With the presence of the third harmonic or multiples thereof in each leg, the neutral point will have a potential to ground since their algebraic sum is not zero at all instants, and therefore circulating currents of triple frequency will flow if a local circuit from this point is presented to these e.m.f.'s of triple frequency rising and

falling at the same time. This may occur with machines operating on the same circuit with neutrals grounded or with a fourth or common return wire. If the phase relation of the third harmonic in each machine is the same, as well as their amplitudes, no circulating currents will flow. With a difference in any of these respects currents of considerable magnitude may flow.

In the case of a delta-connected machine, it may be seen by referring to Fig. 4 again, that Fig. 8 may be taken to represent the condition of affairs for delta connection for the three-phase e.m.f.'s at the time phase $B_1$ is at its maximum, also that Fig. 9 will represent the directions of the third harmonic e.m.f.'s at the same instant in the three legs. In other words, the closed delta presents a local circuit for the third harmonics since they all act in the same direction around the delta and are in phase; hence their effect will




Equation of curve—

$$e = a_1 \text{ Sin } \Phi + a_3 \text{ Sin } 3\Phi + \dots\dots a_{13} \text{ Sin } 13\Phi + b_1 \text{ Cos } \Phi + b_3 \text{ Cos } 3\Phi + \dots\dots b_{13} \text{ Cos } 13\Phi$$

Where—

| | | | |
|---|---|---|---|
| $a_1$ | $= +\ 58.50$ | $b_1$ | $= -\ 0.42$ |
| $a_3$ | $= +\ 0.30$ | $b_3$ | $= +\ 0.054$ |
| $a_5$ | $= +\ 1.25$ | $b_5$ | $= -\ 0.026$ |
| $a_7$ | $= -\ 0.38$ | $b_7$ | $= -\ 0.057$ |
| $a_9$ | $= -\ 0.42$ | $b_9$ | $= +\ 0.30$ |
| $a_{11}$ | $= -\ 1.09$ | $b_{11}$ | $= +\ 0.217$ |
| $a_{13}$ | $= +\ 1.71$ | $b_{13}$ | $= +\ 0.08$ |

FIG. 10—WAVE TAKEN AT NO LOAD; STAR-CONNECTED; VOLTAGE, 2 200; FIELD CURRENT, 30.5 AMPERES

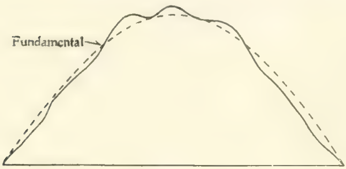
not be zero, but a current of considerable magnitude may flow around the closed delta.

The harmonic e.m.f. induced in each branch of the winding is used in overcoming the internal impedance of the winding, hence when the delta is closed and the local current flows, the harmonic e.m.f. does not appear in the e.m.f. measured between the terminals.

A few years ago the writer undertook the analysis of the wave forms of a three-phase star-connected generator in which circulating currents were known to exist when connected in delta.* The following oscillograms were taken, which show the effect of the third harmonic in a marked degree. The machine in question was of the revolving field type, six open type slots per pole, 425 kw capacity, 2 200 volts, three-phase, 25 cycles, 375 r.p.m.

*The oscillograms in this article were made by Mr. G. H. Bragg, Jr.

The curve in Fig. 10 was taken across two legs star-connected, the curve in Fig. 11 was taken across one leg with delta connection but with one corner of the delta open, the curve in Fig. 12 was taken across one leg with the delta closed. The same field current



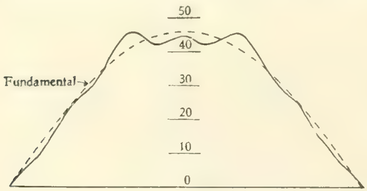

Equation of curve same as in Fig. 10.
Where –

| | |
|---|---|
| $a_1 = +\ 44.76$ | $b_1 = +\ 0.72$ |
| $a_3 = -\ 2.66$ | $b_3 = +\ 0.11$ |
| $a_5 = -\ 0.98$ | $b_5 = -\ 0.03$ |
| $a_7 = +\ 0.26$ | $b_7 = -\ 0.43$ |
| $a_9 = -\ 0.58$ | $b_9 = -\ 0.22$ |
| $a_{11} = -\ 1.05$ | $b_{11} = +\ 0.13$ |
| $a_{13} = +\ 1.15$ | $b_{13} = -\ 0.32$ |

FIG. 11—CURVE TAKEN AT NO LOAD; DELTA OPEN AT ONE CORNER; VOLTAGE, 1 270; FIELD CURRENT, 30.5 AMPERES

was maintained throughout in all cases and no external load applied to the generator operating at normal speed and e.m.f.

An examination of these curves shows considerable difference in their general shape. From the analysis of the curve in Fig. 11 a strong third harmonic is seen to be present, in amount about six percent of the fundamental. It may also be seen that the only other harmonics present of any importance are the tooth harmonics, that is the 11th and 12th. The analysis of the star e.m.f. curve in Fig. 10 shows the practical disappearance of the third harmonics, the other harmonics remaining practically the same. The analysis of the curve in Fig. 12 also shows the practical disappearance of the third harmonic, also that stronger fifth and seventh harmonics have




Equation of curve same as in Fig. 10.

Where –

| | |
|---|---|
| $a_1 = +\ 45.6$ | $b_1 = +\ 0.72$ |
| $a_3 = -\ 0.54$ | $b_3 = +\ 0.11$ |
| $a_5 = -\ 2.60$ | $b_5 = -\ 0.03$ |
| $a_7 = +\ 0.98$ | $b_7 = -\ 0.43$ |
| $a_9 = -\ 0.32$ | $b_9 = -\ 0.22$ |
| $a_{11} = -\ 1.02$ | $b_{11} = +\ 0.13$ |
| $a_{13} = +\ 1.15$ | $b_{13} = -\ 0.32$ |

FIG. 12—CURVE TAKEN AT NO LOAD; DELTA CLOSED; VOLTAGE, 1 270; FIELD CURRENT, 30.5 AMPERES; TWENTY-FIVE PERCENT CIRCULATING CURRENT IN DELTA

been produced due to the pulsations in field set up by the circulating currents.

Although in all cases considered the ninth harmonic in amplitude is practically negligible, both curves in Figs. 10 and 12 show a

decrease of this harmonic when expressed in percent of the fundamental as compared to Fig. 11. A hot-wire ammeter was inserted in the closed delta and with conditions the same as in Fig. 12 it was found that a circulating current of about 25 percent of the full-load current of the generator was present.

That this circulating current was of triple frequency and that at one corner of the open delta there was an e.m.f. of triple fre-

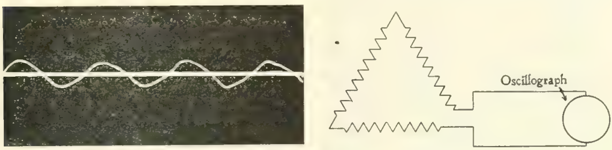



FIG. 13—CIRCULATING CURRENT WITH DELTA CLOSED THROUGH THE OSCILLOGRAPH AS SHOWN AT THE RIGHT

quency is shown by Figs. 13 and 14. The curve in Fig. 13 shows the shape and frequency of the circulating current; while the curve in Fig. 14 shows the e.m.f. wave across one leg and the e.m.f. wave at the open corner of the delta, both taken on the same film. The frequency of the latter is here shown to be three times the former or fundamental. With 1 270 volts across one leg the voltage across the open corner of delta was found to be 266. The phase relation

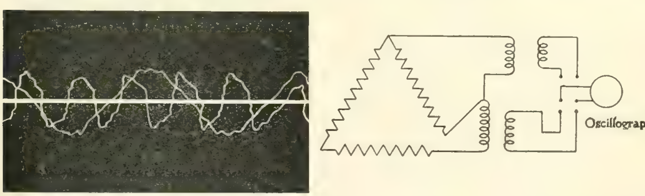



FIG. 14—E. M. F. ON OPEN DELTA = 266 VOLTS; ON NORMAL FIELD = 34.8 AMPERES. THE CIRCULATING CURRENT IS CLEARLY SHOWN TO BE THREE TIMES THE FUNDAMENTAL

and amplitudes of these e.m.f.'s are, of course, not actually as shown in Fig. 14 as transformer's ratios and the relative times of exposures of the same film would have to be taken into consideration to arrive at actual conditions.

To show the effect of the circulating currents on the distribution of flux over a pole, the curves in Figs. 15 and 16 were taken

on one coil of the armature, the effect of the teeth is here somewhat masked due to the breadth factor introduced by the width of coil in one slot. The curve in Fig. 15 was taken with the corner of the delta open and the curve in Fig. 16 with it closed.

It was found that with increased excitations of the machine the circulating currents decreased, owing to the effect of saturation on the flux distribution over the pole face.

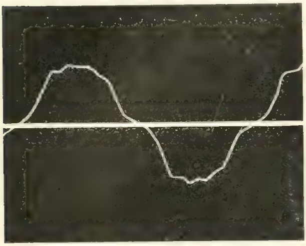


FIG. 15—CURVE TAKEN WITH DELTA OPEN, 43 VOLTS ON ONE COIL, 33 AMPERES CIRCULATING CURRENT, NORMAL FIELD = 34.8 AMPERES

As far as the alternators themselves are concerned these circulating currents have the effect of causing an added iron and copper loss, and if they are to be run close to the limits as regards heating and efficiency the delta connection may be objectionable. With star connection and grounded neutral, these currents can be limited in amount, as a resistance can be inserted in the ground circuit, whereas with delta connection they are dependent on the value of the third harmonics present, which in their turn are dependent on the design and excitation of the generator. From the designer's standpoint the star connection seems to be the safest one to adopt. However, limitations of design met with (as regards specified output, voltage and regulation and armature reaction allowable on frame used) sometimes call for the delta connection; and if these currents are to be kept within limits, due consideration should be given to the shape of pole face, taking into account the ratio of pole arc to pole pitch and the saturation of the magnetic circuit.

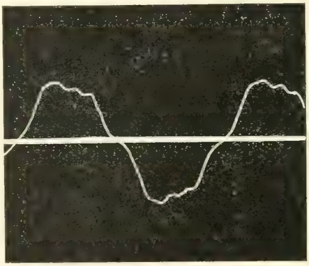
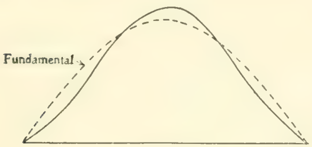


FIG. 16—CURVE TAKEN WITH DELTA CLOSED, 43 VOLTS ON ONE COIL, 33 AMPERES CIRCULATING CURRENT, NORMAL FIELD = 34.8 AMPERES

The curves in Figs. 17 and 18 were taken on another three-phase generator in which the circulating currents amounted to full-load current with no external load on the machine. The shape of

pole faces of this machine were somewhat different from those in the machine just considered. The general shapes of these two curves are seen to be widely different, and the analysis of the curve in Fig. 17, taken with corner of delta open, reveals a strong third harmonic amounting to about 12 percent of the fundamental, whilst analysis of the curve in Fig. 18, taken with delta closed, shows the practical disappearance of the third harmonic and the introduction of a strong fifth, and seventh harmonic as in Fig. 12.

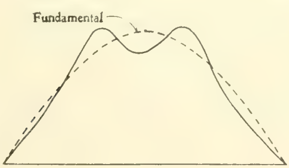



Equation of curve same as in Fig. 10.
Where—

| | |
|---|---|
| $a_1 = + 36.04$ | $b_1 = - 0.63$ |
| $a_3 = - 4.32$ | $b_3 = + 0.30$ |
| $a_5 = - 0.54$ | $b_5 = - 0.33$ |
| $a_7 = - 0.10$ | $b_7 = - 0.17$ |
| $a_9 = + 0.13$ | $b_9 = + 0.27$ |
| $a_{11} = + 0.24$ | $b_{11} = + 0.28$ |
| $a_{13} = + 0.19$ | $b_{13} = - 0.04$ |

FIG. 17—WAVE TAKEN WITH DELTA OPEN, NO LOAD

Whether the increased fifth and seventh harmonics will be objectionable in the external circuit as far as resonance is concerned will depend on the natural frequency of the external circuit, but it will be safe to say that trouble from this respect is very remote. In analyzing these wave forms it was thought sufficient to carry them out as far as the 13th harmonic and the method as found in Jackson's "Alternating Currents and Alternating-Current Machinery" was used.*




Equation of curve same as in Fig. 10.
Where—

| | |
|---|---|
| $a_1 = + 39.8$ | $b_1 = - 0.48$ |
| $a_3 = + 0.14$ | $b_3 = + 0.51$ |
| $a_5 = - 3.93$ | $b_5 = - 1.52$ |
| $a_7 = + 2.40$ | $b_7 = + 1.11$ |
| $a_9 = - 0.59$ | $b_9 = - 0.60$ |
| $a_{11} = + 0.15$ | $b_{11} = - 0.32$ |
| $a_{13} = + 2.34$ | $b_{13} = - 1.62$ |

FIG. 18—WAVE TAKEN WITH DELTA CLOSED, NO LOAD

In order to save time and unnecessary work the accompanying table was prepared so that any curve could be analyzed as far as the 13th harmonic. Similarly tables could be made out for any num-

*On page 696 of this book the following formula will be found:

$$b_m = \frac{2}{n+1}\left[ l_1 \sin\left(m \frac{180}{n+1}\right)^\circ + l_2 \sin\left(\frac{2m\,180}{n+1}\right)^\circ + \ldots\ldots + l_n \sin\left(\frac{nm\,180}{n+1}\right)^\circ \right]$$

$$a_m = \frac{2}{n+1}\left[ l_1 \cos\left(m \frac{180}{n+1}\right)^\circ + l_2 \cos\left(\frac{2m\,180}{n+1}\right)^\circ + \ldots\ldots + l_n \cos\left(nm \frac{180}{n+1}\right)^\circ \right]$$

In this formula *a* and *b* are the maximum value of the sine and the

ber of harmonics. In using this table the base of the curve to be analyzed is first divided into fourteen equal divisions and starting from left to right the points on the base are numbered one, two, three, up to thirteen as in Fig. 19. In column II of Table I (marked "*Values of e*") the values of the ordinates of the wave are put down one after the other. By the use of a slide rule these different values of $e$ can be quickly multiplied by the different sine and cosine values found on the same line in the table as in columns *III, V, VII,* etc., blank spaces for these different products being provided. After this operation columns *IV, VI, VIII,* etc., containing these products are added up, due regard being given to the plus and minus signs found to the right for each case. The algebraic summations of these columns are then multiplied by the value $\left(\frac{2}{N+1}\right)$ which in this case is 1/7. Thus from column IV the values $a_1$ and $a_{13}$ are obtained and from column *VI* the values for $b_1$ and $b_{13}$ are obtained and so on for the rest of the harmonics. These different $a$ and $b$ values can be tabulated in the spaces provided in the lower table and the different phase relations can then be determined from the relation $\tan\theta_m = \frac{b_m}{a_m}$.

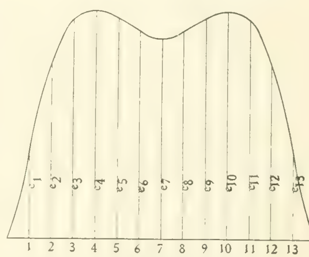



FIG. 19

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cosine components of the mth harmonic and $C_m=\sqrt{a_m^2+b_m^2}$ is the maximum value of mth harmonic. Also $n$ is the greatest number of harmonics sought, which in the above cases was 13 and $e_1$, $e_2$, $e_3$, etc., are the instantaneous values at different points of the wave form to be analyzed. As the base of the wave form is divided into n+1 equal divisions or 14 in the cases considered, there are $n$ points between $\alpha=0$ and $\alpha=180^\circ$

The use of the formula in the above shape is tedious and mostly repetition, as it will be noted the sine and cosine values for the angles $\left(m\frac{180}{n+1}\right)^\circ$ and $\left(2m\frac{180}{n+1}\right)^\circ$ etc., can be determined once for all curves analyzed as far as any one value of $n$. It will also be found that the above equation for the first and 13th harmonics will be identical, with the exception of the plus and minus signs, similarly for the third and eleventh harmonics, etc.

TABLE I—ANALYSIS OF WAVE TO 13 HARMONICS

| I | II | III | IV | | | V | VI | | | VII | VIII | | | IX | X | | | XI | XII | | | XIII | XIV | | | XV | XVI | | XVII | XVIII | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pt. | Value of e | Sin $\phi$ | e Sin $\phi$ | $a_1$ | $a_{13}$ | Cos $\phi$ | e Cos $\phi$ | $b_1$ | $b_{13}$ | Sin $\phi$ | Sin $\phi$ | $a_3$ | $a_{11}$ | Cos $\phi$ | e cos $\phi$ | $b_3$ | $b_{11}$ | Sin $\phi$ | e Sin $\phi$ | $a_5$ | $a_9$ | Cos $\phi$ | e Cos $\phi$ | $b_5$ | $b_9$ | Sin $\phi$ | e Sin $\phi$ | $a_7$ | Cos $\phi$ | e Cos $\phi$ | $b_7$ |
| 1 | *7.8* | .222 | *1.73* | + | + | .975 | *7.6* | + | — | .623 | *4.86* | + | + | .782 | *6.10* | | — | .901 | *7.03* | + | + | .434 | *3.38* | + | — | 1 | *7.8* | + | 0 | *0* | [illegible] |
| 2 | *18.0* | .434 | *7.80* | + | — | .901 | *16.2* | + | + | .975 | *17.55* | + | — | .222 | *4.00* | + | + | .782 | *14.08* | + | — | .623 | *11.20* | — | — | 0 | *0* | + | 1 | *18.0* | — |
| 3 | *26.0* | .623 | *16.15* | + | + | .782 | *20.3* | + | — | .901 | *23.40* | + | + | .434 | *11.28* | — | [illegible] | .222 | *5.76* | — | — | .975 | *25.30* | — | + | 1 | *26.0* | — | 0 | *0* | — |
| 4 | *33.5* | .782 | *26.2* | + | — | .623 | *20.85* | + | + | .434 | *14.50* | [illegible] | — | .901 | *30.20* | — | — | .975 | *32.60* | — | [illegible] | .222 | *7.43* | | — | 0 | *0* | + | 1 | *33.5* | [illegible] |
| 5 | *44.0* | .901 | *39.6* | + | + | .434 | *19.10* | + | — | .222 | *9.76* | — | — | .975 | *42.90* | — | + | .623 | *27.40* | — | — | .782 | *34.4* | [illegible] | — | 1 | *44.0* | + | 0 | *0* | |
| 6 | *43.8* | .975 | *42.6* | + | — | .222 | *19.71* | + | [illegible] | .782 | *34.2* | — | + | .623 | *27.30* | — | — | .434 | *19.0* | + | | .901 | *39.4* | + | + | 0 | *0* | + | 1 | *43.8* | — |
| 7 | *47.7* | 1 | *47.7* | + | + | 0 | *0* | + | [illegible] | 1 | *47.7* | | — | 0 | *0* | — | — | 1 | *47.7* | + | | 0 | *0* | [illegible] | + | 1 | *47.7* | — | 0 | *0* | — |
| 8 | *43.5* | .975 | *42.4* | + | — | .222 | *9.65* | | — | .782 | *34.0* | — | + | .623 | *27.10* | | + | .434 | *18.9* | + | — | .901 | *39.2* | — | — | 0 | *0* | + | 1 | *43.5* | [illegible] |
| 9 | *42.8* | .901 | *38.6* | + | [illegible] | .434 | *18.60* | — | [illegible] | .222 | *9.48* | — | — | .975 | *41.70* | [illegible] | — | .623 | *26.6* | — | | .782 | *33.5* | — | + | 1 | *42.8* | + | 0 | *0* | [illegible] |
| 10 | *34.2* | .782 | *26.7* | + | | .623 | *21.30* | | — | .434 | *14.8* | + | | .901 | *30.80* | [illegible] | + | .975 | *33.3* | — | [illegible] | .222 | *7.58* | + | + | 0 | *0* | + | 1 | *34.2* | — |
| 11 | *24.7* | .623 | *15.4* | + | [illegible] | .782 | *19.30* | — | + | .901 | *22.2* | + | + | .434 | *10.70* | [illegible] | | .222 | *5.48* | — | | .975 | *24.10* | + | — | 1 | *24.7* | — | 0 | *0* | — |
| 12 | *16.0* | .434 | *6.93* | + | — | .901 | *14.40* | | [illegible] | .975 | *15.6* | + | — | .222 | *3.55* | — | — | .782 | *12.50* | + | — | .623 | *9.97* | [illegible] | | 0 | *0* | + | 1 | *16* | + |
| 13 | *5.6* | .222 | *1.24* | + | | .975 | *5.46* | — | + | .623 | *3.49* | + | + | .782 | *4.39* | — | + | .901 | *5.05* | + | + | .434 | *2.43* | — | [illegible] | 1 | *5.6* | + | 0 | *0* | + |

| | | | | | |
|---|---|---|---|---|---|
| $a_1$ | $+$ *11.76* $b_1$ | *.19* $e_1$ | *11.77* tan | $\theta_1$ *.0161* | $\theta_1$ *0° 55′* |
| $a_3$ | $-$ *2.66* $b_3$ $+$ | *.11* $e_3$ | *2.68* tan | " $_3$ *.041* | " $_3$ *2°—21′* |
| $a_5$ | $-$ *.98* $b_5$ $-$ | *.03* $e_5$ | *.98* tan | " $_5$ *.0306* | " $_5$ *1° 45′* |
| $a_7$ | $+$ *.26* $b_7$ $-$ | *.13* $e_7$ | *.30* tan | " $_7$ *.165* | " $_7$ *9°—21′* |
| $a_9$ | $-$ *.58* $b_9$ | *.22* $e_9$ | *.62* tan | " $_9$ *.38* | " $_9$ *20° 48′* |
| $a_{11}$ | $-$ *1.05* $b_{11}$ $+$ | *.13* $e_{11}$ | *1.06* tan | " $_{11}$ *.124* | " $_{11}$ *7°— 6′* |
| $a_{13}$ | $+$ *1.15* $b_{13}$ | *.32* $e_{13}$ | *1.19* tan | " $_{13}$ *.278* | " $_{13}$ *15°—36′* |

This table has the values for the curve given in Fig. 11 filled in in italics as an example. The same form of table may be used for the other curves and filled in in the same way. The values of $a_1$, $b_1$, etc., are deduced and given in the lower part of the table at the left, thus the summation of column IV = 313.35. $\left(\frac{2}{n+1}\right)$ or $\frac{1}{7} \times 313.35 = 44.76 = a_1$, as given in the lower table.

# RAILWAY SIGNALING—III

## ELECTRIC INTERLOCKING

J. D. TAYLOR

A VERY long stride in the direction of improved interlocking apparatus was made when electricity came into use as the motive power for operating the switches and signals. That the use of electricity for the purpose supplied a want, is proved by the rapidity with which electric interlocking has assumed a place second to none in the estimation of the railroad world. Electric interlocking was first introduced commercially in 1900. Since that time growth in the number of installations has been very rapid; the number increasing in a geometrical ratio such that the number of installations in any year exceeds that of the two preceding years combined.

The superiority of electricity as a motive power in interlocking work, as well as for a great many other purposes, is due to the facility with which it can be stored and retained for indefinite periods of time with very small loss from leakage, and to the small loss incurred in transporting it from the point where it is generated or stored, to the point where it is to be used. The conversion of electrical into mechanical energy can be effected with a high degree of efficiency, the question of efficiency of conversion, being, however, of less importance in interlocking work than the high degree of insulation that is possible to attain. The circuits of an interlocking plant can easily be so well insulated that the loss on account of leakage is practically nothing, and faults in insulation can very easily be detected and removed; in fact, immediate attention is called to faults of a serious nature in electric circuits, by their interference with the proper operation of the plant.

When a switch lever in a mechanical interlocking plant is moved from normal to reverse and latched, the locking between it and the signal lever, controlling the signal-governing movements over the switch reversed, is immediately released. When the lever is reversed and latched, it is assumed that the switch has followed the movement of the lever and is also reversed and locked. The possibility of the pipe line breaking, or buckling enough to allow the lever to be put into full reversed position with the switch only partly reversed, is not considered. But when electric power is used

for operating the switches (and the same may be said of other forms of power), the movement of the lever merely turns on the power and it is not safe to assume that the switch necessarily follows the movement of the lever and takes up a position corresponding. The circuit may be open at any one of a number of places so that current will not reach the motor at all; or the movement of the switch may be obstructed so that the motor is unable to move it. In order that there may be no failure of the switch in responding to the movement of its controlling lever, resulting in dangerous consequences, the lever movement is divided into two parts: the preliminary movement for closing the operating circuit of the motor and the final movement for releasing the locking of other levers. The lever is stopped at the end of the preliminary movement by a latch known as the indication latch, because its disengagement from the lever serves as an indication that the switch

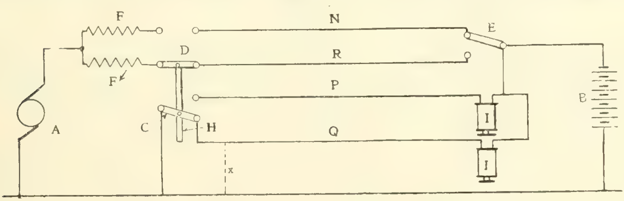



FIG. I

has been moved home and locked. The latch is lifted and the lever freed to make its final movement at the proper time by an electromagnet or motor known as the indication magnet or the indication motor.

The necessity for an indication or automatic release of the locking when power of any kind is used for operating switches, was recognized from the first, but the problem still confronting the signal engineer was to find a suitable source of current for energizing the indication magnet. The first thought that would occur to one trying to solve the problem, would be to employ the main source of current used in operating the plant, for energizing the indication magnet, and have the switch mechanism operate a circuit controller to close the indication circuit at the proper time. Such a method is shown diagrammatically in Fig. 1, divested of most of the apparatus and circuit controllers not directly concerned in the formation of the indication circuits. An indication circuit is

closed in either extreme position of the track switch, by the circuit closer C actuated by the rod H which is connected to some point of the switch movement, preferably to the lock bar. It can easily be seen by a mere inspection of the diagram, that an accidental contact of the wire Q with the common return wire, such as could easily happen through faulty insulation, and as indicated by the dotted line X, would cause an indication to be given irrespective of the position of the controller C and, therefore, irrespective of the position of the track switch. An actual contact of the two wires is not required to produce this result. If both are grounded the effect is the same. No matter how good the insulation may be or how carefully the work of construction and installation may be done, there is always the possibility that the insulation may break down. An indication given by a current drawn from the main source of supply

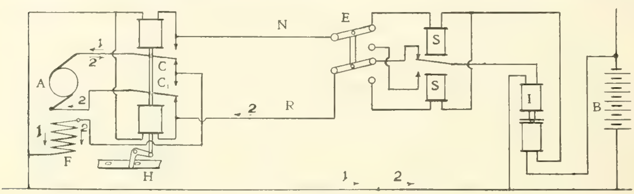



FIG. 2

which operates the plant, is, therefore, little better than no indication at all. It will be noticed that this method of operation and indication requires four wires, two operating and two indication, extending between the lever and the switch, in addition to a wire which is common to all switches lying in the same general direction from the cabin.

### DEVELOPMENT OF ELECTRIC INTERLOCKING

The first real step towards developing a practical system of electric interlocking, was made when a means was discovered for utilizing a current generated by the switch operating motor itself, for actuating the indication magnet. This method is illustrated by Fig. 2 in which the parts are shown in the proper connection for generating the indication current. During the switch movement supposed to be just completed, the controller CC′ was in the upper position when current flowed through the armature and fields in the direction of the arrow *1*, and the counter electro-motive force had

the direction indicated by the arrow *2*. At the instant the switch movement is completed, the controller $CC'$ is shifted to the position shown, which puts the motor and indication magnet on a circuit independent of the battery. The electro-motive force induced in the armature, which is still rotating due to the momentum previously acquired, drives a current, through the indication magnet in the direction of arrows *2*. It is obvious that the only effect that a connection between the wire $R$ and the common wire could have, would be to prevent current reaching the indication magnet; thus the error, if any, would be on the side of safety. If the wire $R$ should by accident become connected to $N$, current would flow through the indication magnet, but harm from this is prevented by putting another magnet with its coils in circuit with the wire $N$, directly under the indication magnet, so that the indication armature rests normally on its poles. So long then as current is flowing in the wire $N$, the indication magnet will be unable to lift the armature, no matter how strongly it may be energized. If the wire $N$ should be broken and another live wire should at the same time become connected with the wire $R$, a false indication might result; but this requires the simultaneous happening of two things, either of which alone would be immediately discovered and removed. Interlocking apparatus is considered safe when its wrong operation requires such a coincidence.

The apparatus shown at $S$ is employed for removing the only remaining chance for false indication, not taken care of by the means previously mentioned. It comprises two magnets, one in each operating circuit, acting on a contact lever capable of bearing on a fixed contact on either side. The lever and contacts form a circuit switch, the function of which is to close the proper indication circuit. If the operating circuit is good so that current flows in it, the corresponding indication circuit will be closed, but then current will flow in the safety magnet under the indication magnet and will prevent a premature indication. If the operating circuit happens to be open, the corresponding indication circuit will not be closed, so that it will be impossible for a stray current to reach the indication magnet.

It will be noticed that in Fig. 2 only two wires, besides the common wire, are required for the operation and indication of the switch: the operating wire for one movement becomes the indication wire for the next movement. This system, therefore, is not only much safer than that using the main battery for indications, but requires only a little more than half as much wire.

Fig. 3 shows an entirely different method of obtaining a safe and reliable indication of the movements of the switch. In this the indication current is drawn directly from the main battery, but it is transformed into an alternating current, and an alternating-current induction motor is employed for actuating the indication latch. The transformation of the battery current into an alternating current is effected by means of a transformer and an apparatus for varying the strength of the current in its primary coil. The transformer is located in the cabin and its primary coil is included in the operating circuit. The secondary coil is connected directly to a small induction motor provided with suitable gearing to cause the rotation of the armature to lift the indication latch. The apparatus for producing the variations in the current should be located at the switch, so that the circuit closer actuated by the switch mechanism for closing the indication circuit may be between this apparatus and the transformer. A convenient means for producing the variations in the current is afforded by a collector ring on the armature shaft of the switch operating motor, connected to one segment of the commutator. At the end of the switch movement, after it has been locked, and after the motor has been disengaged from the mechanism by the clutch interposed between the motor and the mechanism for the purpose, the operating wire is switched from the operating brush to the brush bearing on the collector ring. The motor armature will continue to rotate, driven by the current entering by way of the collector ring and passing out by way of the brush connected to the common wire, and as the segment to which the ring is connected alternately approaches and then recedes from the common brush, the current in the circuit including the primary coil of the transformer will rise and fall alternately. The undulatory current thus produced, induces magnetism of a like character in the iron core, which in turn generates an alternating current in the secondary coil. The current from the secondary flows through the

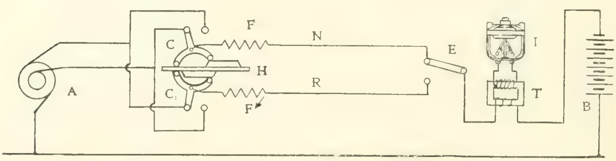



FIG. 3

coils of the induction motor causing a rapid rotation of the armature which results in lifting the indication latch.

It can easily be seen that a connection either accidental or intentional of the wire $N$ with any other wire, would cause only a direct current to flow through the primary coil of the transformer, which would have no effect on the secondary except to produce a single impulse at starting of the current and again at stopping. Such impulses have only a barely perceptible effect on the armature of the induction motor, and no effect, whatever, on the "centrifuge" by means of which the rotation of the armature is converted into a direct axial thrust. As the induction motor is built to require approximately one hundred alternations per second to make it operative, it is quite apparent that it could not be affected by any succession of impulses that could be produced by accident. The accidental contact of the wire $N$ with the wire to another switch which is in the act of indicating, could not result in a false indication, because it is in connection with the operating brush of the motor until the movement is completed, which would hold it at a uniform potential either high or low and would prevent fluctuation.

It will be noticed that this system, also, requires only two wires between the operating lever and the switch; the operating wire for any movement becoming the indication wire for the same movement. During the entire movement in either direction except a small part at the end of the movement, the two wires lead to the operating brush of the motor. Two field coils $F$ and $F'$ are provided, one in each operating wire, for the purpose of reversing the direction of the movement at any point. The field coils are so connected that currents through them from the battery produce opposite magnetizing effects, while the current always flows in the same direction through the armature. A simple means is thus afforded for reversing the direction of rotation of the motor armature, which is effected by merely changing the position of the operating lever and thus connecting one or the other operating wire to battery. The quality of reversibilty is of considerable importance, for it sometimes happens that the movement of the switch points is obstructed by something that prevents the point coming up solidly against the stock rail. If, in such an event, the switch can be put back to its original position, other routes will be freed that would be locked up if the lever had to remain in its intermediate position until the obstruction is removed. Again, the obstruction may be of such a nature that it may be crushed and might fall out of the way if the pressure of

the point were removed. A second attempt would then secure the desired movement.

Two field coils cannot be used for reversing the motor with the system shown in Fig. 2, because, as will be seen later, such means for reversal would interfere with the proper performance of the functions of another essential piece of apparatus. Reversibility is secured by attaching the cores of two solenoids to the rod connecting the blades of the controller *CC'*. By means of these solenoids, one of which is in each operating circuit, the controller *CC'* may be manipulated from the cabin.

### SWITCH OPERATION BY STRAY CURRENTS

There is one other consideration quite as important as the indication, which must receive due consideration in the design of an electric interlocking system, and that is, the provision of means for preventing a stray current reaching a switch or signal motor, and

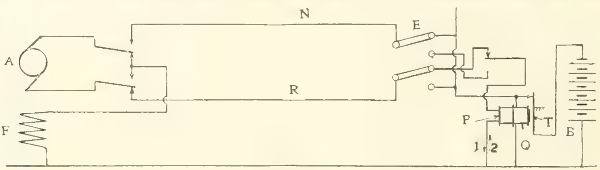



FIG. 4

causing an improper movement of the switch, or a clear indication by the signal when the track ahead may not be in proper condition for a train to pass. An improper movement of a switch, due to a stray current reaching it through faulty insulation, would have practically the same result as a false indication, as it would put the switch in a position not corresponding with the position of the lever; but, if there is any difference, the condition would be more dangerous, as there would not be as much likelihood of its being discovered by the operator.

Fig. 4 shows a very effective means for guarding against improper movements of switches and signals by stray current, as applied to the system illustrated in Fig. 2. This means comprises a circuit breaker held normally closed by current in the coils of an electro-magnet. The electro-magnet has two coils, one a high resistance coil *Q* continuously in circuit with the main battery, and the other a low resistance coil in the common lead of the indication circuits. If current flows in the coil *P* in a direction to make its

influence additive to that of *Q*, no effect is produced; but if it flows in the opposite direction, the magnet will be neutralized and the circuit breaker *T*, released, thus opening the main lead from the battery and cutting off current from the entire plant. Each indication current passes through the coil *P*, but in the direction of the arrow *2*, in which direction it aids the coil *Q* in holding the circuit breaker *T*; but a current from a live wire in contact with the wire *R* or any of its connections would flow back through the coil *P* in the direction of the arrow *1* and would cause the circuit breaker *T* to open the circuit. It can now be seen why two field coils cannot be used for reversing the switch operating motor, for the use of such coils for the purpose would cause the indication current to flow in the direction of the arrow *1*, and would open the circuit breaker *T* at each movement of a switch. It can easily be seen

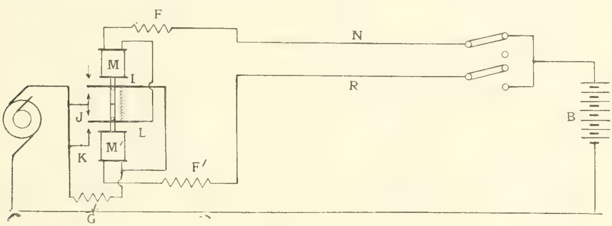



FIG. 5

that the effectiveness of the device as a protection depends on the wire *R* being unbroken from the point of improper contact, back through the coil *P*, to common. But this wire was used as indication wire in making the last movement and if it had been broken then the break would have been discovered and repaired. A failure, therefore, requires, practically, the simultaneous happening of two things either of which alone would be discovered and repaired on the first attempt to operate the switch. All apparatus used in connection with the operation and indication of the switch and not directly concerned in the operation of the safety device, has been omitted from the diagram.

Another form of safety device adapted especially to the system shown in Fig. 3, is illustrated in Fig. 5. This apparatus is located near the switch motor and comprises two solenoids for operating circuit controllers. Only enough of the circuits are shown to illustrate the principles of its action in preventing improper movements.

The instrument also serves to open the circuit and stop the current when the lever movement is completed, and to switch the indication wire from the brush bearing on the collector ring, to the operating brush preparatory to the next movement. The wire $R$ is the one that will be used to lead current to the motor for effecting the next movement of the switch. The preliminary circuit includes the field $F'$, magnet $M'$, lever $L'$, and resistance $G'$. Current in this circuit will energize the magnet $M'$, causing it to attract the lever $L$ which it will pull up against the contact $K$. If the current is properly started by a movement of the controlling lever in the cabin, the lever $L'$ will also be drawn back against the contact $J$, thus cutting the resistance $G'$ out of the motor circuit; but if the current enters the wire $R$ through faulty insulation the lever in the cabin not having been moved, a current will flow in the circuit including the field $F$, magnet $M$, lever $L$, and the armature, and will result in holding the lever $L'$ away from the contact $J$. The latter circuit has no extra resistance in it, while the former includes the resistance $G$. The current through the field $F$ will, therefore, be very much stronger than that through $F'$, and it will determine the polarity of the field magnet, which will be the same as it was in making the last movement. The motor armature will, therefore, rotate idly in the direction it did in making the last movement, and without any effect on the switch mechanism. It may be well to mention here that the motor armature is connected to the mechanism by means of a clutch which permits the motor to be disengaged at the end of each movement, and to run without load while transforming the current for indication. It also runs without load when the safety device becomes operative to prevent an improper movement. The counter electro-motive force of the motor acts as a resistance to limit the current required to operate the safety device to three or four amperes. The circuits, both that improperly charged and the safety circuit, lead to the same brush of the motor. The former includes the resistance $G'$ which, with the maximum resistance in the lines, reduces the current in the field $F'$ to one-fifth that in the field $F$.

It will be noticed that, in this method as in that previously described, the action of the safety device depends on the continuity of a wire. In this case it is the wire which was last used in operating the switch and which must have been good when the last movement was made. The two methods are, therefore, equal in the degree of safety afforded. There is one point of difference that may

be worth mentioning. The safety device shown in Fig. 5, when it becomes operative, affects only the switch to which it is connected, while that shown in Fig. 4 throws the whole plant out of service, or as much of it as is connected to one common return. If the circuit breaker *T* is cut into the common instead of the main positive lead, and one cut-out is provided for each common return, then when one of them is opened by an improper connection, only that part of the plant served by that common return is put out of service. Obviously, this principle could be extended, so as to cut out only one switch, by using a separate return for each switch instead of a common wire, and by putting a cut-out in each return.

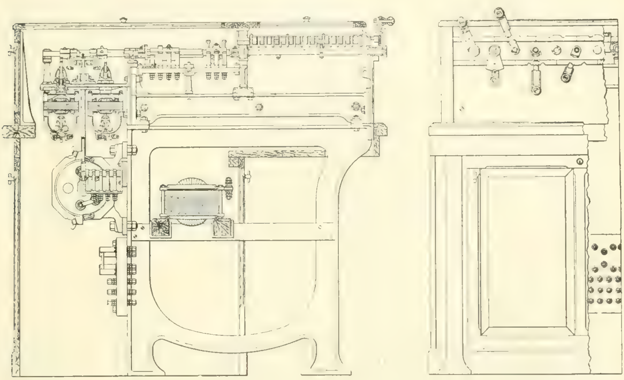
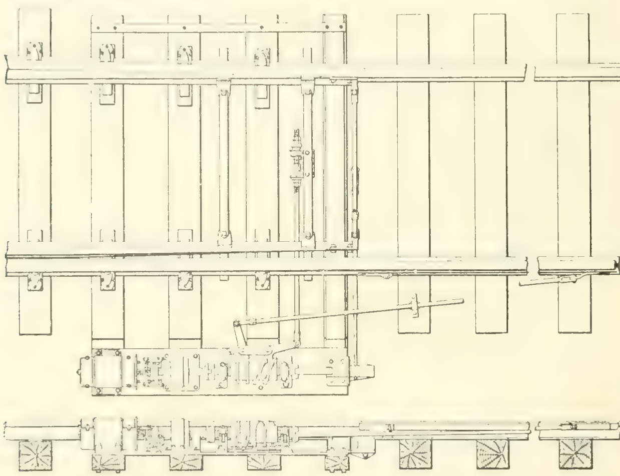


FIG. 6—VIEWS OF ELECTRIC INTERLOCKING MACHINE SHOWING END AND FRONT ELEVATION

After what has been written in preceding articles descriptive of interlocking apparatus, an extended description of the apparatus used in connection with the all-electric system is unnecessary. A brief description of the more important parts peculiar to the electric system may, however, be of interest.

An interlocking machine now in quite extensive use, is shown in Fig. 6. This resembles very much, in general appearance, the electro-pneumatic machine described in a preceding article in the Journal. The only real point of difference is in the indication apparatus which, for the electric machine, is adapted to the alternating current described in connection with Fig. 3. The indication motor has its armature shaft in a vertical position, to which is at-

tached a piece of centrifugal apparatus very similar in construction to the well known form of governor used on the steam engine. The rapid rotation of the armature causes the weights to separate, and through a system of levers, to lift the indication latch and release the lever. This mode of construction makes it necessary to have a very rapid rotation of the indication motor armature to produce the desired effect, and this rotation can be secured only by a rapid succession of alternating impulses in the coils of the motor. A direct current through these coils has no effect other than to lock the armature against rotation.



FIGS. 7 AND 8—PLAN AND ELEVATION SHOWING ELECTRIC SWITCH AND LOCK MOVEMENT

SWITCH AND LOCK MECHANISM

Fig. 7 is a plan and Fig. 8 a side elevation, showing a switch and its operating mechanism. The switch and lock movement is driven by a direct-current motor of about 1.5 hp, designed to be operated at 110 volts. The shaft of this motor is connected by means of a magnetic clutch to a shaft extension in the same line, working a cam drum, which operates the switch and lock. Intermediate between the magnetic clutch and drum, there is a reduction gearing

with a speed ratio of twenty-five to one. It will be noticed that there are two cams on the drum, one of these working the lock rod and detector bar, and the other the switch, connection being made to the detector bar and switch through cranks. The lock is worked direct by a straight bar which slides longitudinally underneath the cam, motion being imparted by means of a lug fitting the cam slot. It will be noticed that in each case the cam slot, for a portion of its travel, moves in a plane at right angles to the shaft, so that while that portion is passing the hub on the driving bar or crank, no movement of the latter takes place; it is only while the hub is engaged by the diagonal portion of this slot, that movement is imparted to the switch or lock mechanisms. The operation is therefore on the principle of the switch and lock movement, with which signal engineers are quite familiar, and briefly is as follows: When the drum is revolved by the motor, the lock rod and detector bar immediately begin to move, and as soon as these have completed their stroke, the motions of these mechanisms cease and the movement of the switch begins. After the switch has been moved over against the stock rail, further motion of the lock bar locks the switch and at the same time operates a knife switch which opens the control circuits and closes the indication circuit.

A noticeable feature of this switch and lock movement is the arrangement of the parts in one long and narrow mechanism which occupies but little space between the tracks. For this reason it can be used in many places between tracks that come too close together to admit movements of other design, which in some places must be placed outside the tracks with long rod connections, passing under intermediate tracks to the switch. Another feature of this design worth noticing, is the fact that the cam drum is reversible, so that the movement can be operated either right or left, merely by changing the drum end for end, the position of the motor and clutch remaining the same. The motor, clutch, and drum are all attached to a steel base plate.

Returning now to the motor part of the movement; the direction of rotation for reversing the switch is controlled by means of a double field winding, one part of which is cut out while the other is in circuit. When the switch is to be thrown in the reverse direction, the lever on the interlocking machine merely changes the connection of the operating circuit to the other field winding.

The use of the magnetic clutch is an advantage in several ways. It permits the breaking of the motor connection with the throwing

mechanism instantly and at the proper time, and the absence of a rigid connection prevents breaking or straining of the parts if the movement of the switch should become blocked, as by the dropping of a lump of coal or other obstruction. The blocking of the switch

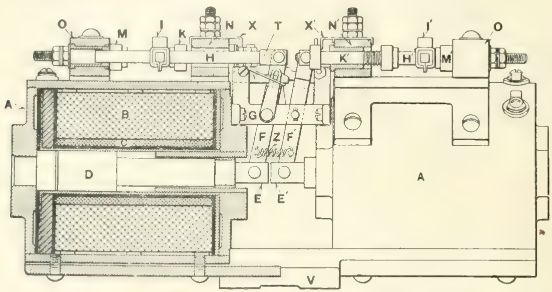


FIG. 9—SIDE ELEVATION OF SOLENOID SAFETY CIRCUIT CONTROLLER FOR SWITCH MOVEMENT

merely causes the clutch to slip until a fuse is blown on the interlocking machine. It should here be noted that the motion of the switch follows the lever. If the switch is found to be blocked, it can be thrown back by simply reversing the lever.

SAFETY CONTROLLER FOR SWITCHES

The safety controller used with the system shown in Fig. 5, and which automatically cuts out a switch motor if the lines be-

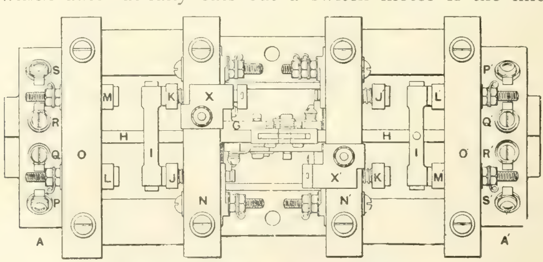


FIG. 10—PLAN VIEW OF CIRCUIT CONTROLLER

come improperly connected, combines in one, the functions of two electro-magnetic circuit controllers. The function of one is to open the motor circuit when the lever movement is completed, and of the other to open the next operating circuit when it is energized by con-

nected wires, and thus to prevent a wrong movement. The instrument which is illustrated in Figs. 9, 10, 11 and 12 comprises two solenoids *A* and *A*, fixed to a cast iron base *V*. Each solenoid has a moveable core *D*, connected by means of a jaw *E* to a lever *F*.

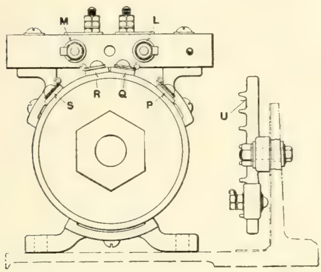



FIG. 11—END ELEVATION OF CIRCUIT CONTROLLER

a movable core *D*, connected by means of a jaw *E* to a lever *F*. The lever *F* is pivoted at its middle to a fixed support *G* and is connected at its upper end to a rod *H*, free to move longitudinally. The rod *H* carries a contact bridge *I*, which will connect the contact points *J* and *K* when the core *D* is drawn into the solenoid, and will connect the contact points *L* and *M* when the core *D* is drawn outward. The levers *F* and *F′* are connected near the lower ends by a spring *Z*, which causes the bridge *I′* to connect *L′* and *M′*, when the core *D* is drawn into its solenoid *A* to nearly the full extent. Similarly the contact bridge *I* is made to connect *L* and *M* when the core *D′* is drawn into the solenoid *A′*. The contacts *J* and *K* are carried by the slate block *N*, with springs interposed so that they may be pushed in about three-sixteenths of an inch. The contacts *L* and *M* are fixed to the slate block *O*. The relation of the parts is such, that the bridge *I* touches the contacts *J* and *K*, while the core *D* is still three-sixteenths of an inch from its complete forward stroke, and the bridge *I′* touches *L′* and *M′* with the core D about one-sixteenth of an inch from its full inward stroke. These clearances are allowed for making good contact. Each solenoid has two coils of wire. The coil *C* has 100 turns of No. 13 B. & S. gauge and the coil *B*, 1 100 turns of No. 15 B. & S. gauge. The resistance coils *U* and *U′*, each of twenty ohms, are in series with the coils *B* and *B′* at the starting of a movement, and the circuits including them may be called the starting circuits. The coil *B* is connected to terminals *P* and *Q*, and the coil *C* is connected to terminals *R* and *S*.

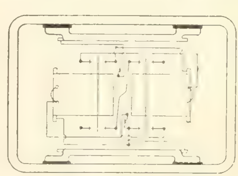


FIG. 12—WIRING DIAGRAM

At the beginning of a movement, current flows through coils $C$, $B$, and $U$ in series, and draws in the core $D$, causing the bridge $I'$ to connect $L'$ and $M'$, which shunts the coils $B$ and $U$, so that the operating and indicating currents flow only through the coil $C$, of a very low resistance, but having sufficient turns to hold the core $D$ in place. The bridge $I$ will touch $J$ and $K$ before $I'$ touches $L'$ and $M'$, so that if the current happened to come from a foreign source without the lever having been moved, current would also flow from the last operating wire, which is still in connection with battery, through coils $C'$, $B'$, bridge $I$, and the motor, and would hold $I'$ away from $L'$ and $M'$, by drawing in the core $D'$. This current will run the motor light in the direction it ran in making the last movement, and without energizing the clutch. The contact $K$ is provided with a head on its inner end, which makes connection with a contact $X$, when $K$ is pushed outward by the spring, but when $K$ is pushed in by the bridge $I$, it is separated from $X$. The object of this is to cause the cut-off current to flow only through the safety contacts $J$ and $K$, and thus afford a test of their condition at each movement of the switch.

When the core $D$ is drawn completely into the solenoid $A$, the latch $T$ drops into the path of a projection on the lever $F'$, so that if the magnet $A'$ is energized while $A$ is still holding its core, the core $D'$ will be stopped by the latch $T$ before it puts the bridge $I'$ against $J'$ and $K'$. A similar latch, $T'$, stops the core $D$ under similar conditions. These latches come into play in the action of the cut-off current. If in that case the bridge $I'$ were allowed to move far enough to touch $J'$ and $K'$, the safety circuit would be temporarily closed and cause sparking at the contacts.

# MULTI-GAP LIGHTNING ARRESTERS WITH GROUND SHIELDS

R. B. INGRAM

THE multi-gap type of lightning arrester has various modified forms and arrangements, the most commonly known being the low equivalent type and the multiplex type. In selecting lightning arresters of the multi-gap type for any particular service the voltage of the system should be known and the arrester set to discharge at a predetermined minimum value. It was long ago observed, without being very thoroughly understood, that arresters of the same design possess a varying minimum discharge point, the variation being due apparently to varying local conditions. Some manufacturers have sought to overcome this variation of the minimum discharge potential by introducing an adjustable spark gap in series, on the line side of the multi-gaps of the arrester. This expedient has not proven entirely satisfactory for all conditions and in the further investigation of the operation of lightning arresters of the multi-gap type, some notable phenomena have been observed regarding the effect of variation in the relative position of the multi-gaps and the ground and the distance between them. These observations have resulted in the development of a simple but effective device that serves to practically eliminate the effect of these local conditions and in addition to practically eliminate another effect that becomes a serious problem in the design of arresters for the higher potentials, viz., the observed diminution in voltage-sustaining power of the respective spark gaps of a multi-gap series as the number gaps is increased for high voltage service.

When a series of small air gaps between metal cylinders one-half inch in diameter, for example, with gaps of approximately one thirty-second of an inch are placed between the terminals of a generator or transformer and the potential is raised to a point where the gaps just fail to break down, the potential tends to distribute itself throughout the series. The air gaps act in a manner similar to condensers in series, each gap taking a potential in an inverse proportion to its capacity. The cause of the rapid falling-off in voltage sustaining power is due to the "ground potential influence." The intensity of this ground influence is dependent on the method of connecting the gaps in circuit and the distances to the surrounding grounds.

Curve *A* in Fig. 1 shows the breakdown potential of a certain series of one thirty-second inch air gaps, for a particular set of conditions, when one side of the circuit is grounded. Curve *B* shows the breakdown potentials when the circuit is ungrounded. The voltage sustaining power per gap unit decreases rapidly as the impressed voltage increases from 15 000 to 75 000. Beyond this latter voltage additional gaps have little influence in increasing the voltage sustaining power of the series. In addition to the potential across the air gaps between adjacent cylinders there is also a

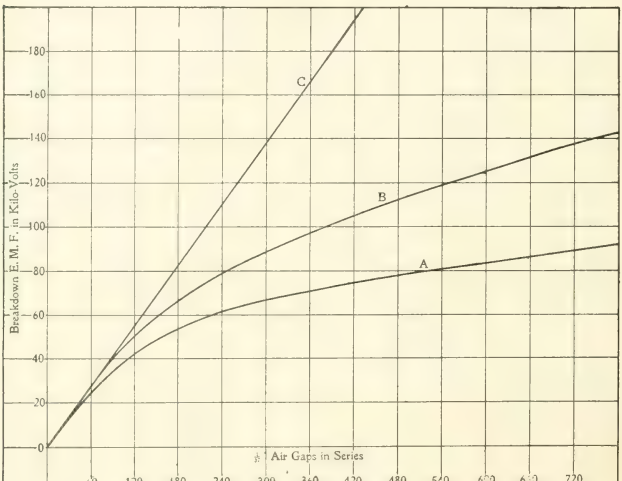



FIG. 1—CURVES SHOWING BREAKDOWN VALUES OF A SERIES OF SMALL AIR GAPS BETWEEN METAL CYLINDERS FOR GROUNDED, UNGROUNDED AND SHIELDED CONDITIONS

strain or difference of potential between each cylinder and the ground. This strain may be represented approximately at each point of the series by a gradient such as is shown in Fig. 2. When one side of the circuit is grounded the strain between the first cylinder on the ungrounded side and the ground is equal to full line potential, but becomes less and less on successive cylinders until zero potential is reached on the ground side. The dotted line shows the change in distribution of the ground strain when the circuit is ungrounded. The strains to grounds produced at either end, of

the ungrounded series, are equal to approximately one-half of full line potential and decrease to zero at the centre of the series.

EFFECTS PRODUCED

It is well known that when an insulated conductor is raised to approximately 20 000 volts difference of potential from a conductor immediately adjacent to it an atomic structural rupture of the air immediately surrounding the conductors will occur, a conduction of current resulting. The minimum e.m.f., at which the atmospheric dissociation will occur at ordinary temperatures and barometric

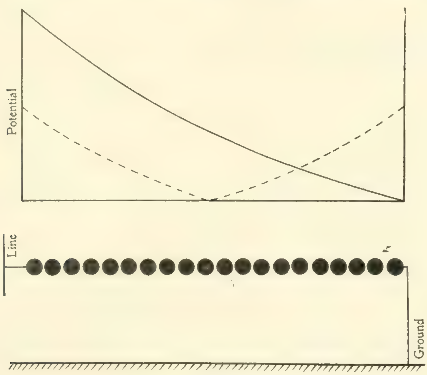



FIG. 2—CURVES SHOWING THE DISTRIBUTION OF STRAIN TO GROUND OVER A SERIES OF SMALL AIR GAPS SEPARATED BY METAL CYLINDERS ARRANGED AS SHOWN

pressures, depends upon a number of factors and may be expressed by the following equation—

$$^{*}\,E\ (\text{max.}) = 2055 \log_{10} \times \frac{S}{R} \times D' \times (r+d) \times 10^{10}$$

in which—

*E (max.)*=the maximum value of the voltage wave.

*r*=the radius of the line conductor in inches,

*s*=the separation of the line conductor in inches.

*d*=the distance from the conductor at which the strain due to the electro-static field causes initial atmospheric rupture.

*D′*=the strength of the electro-static field of force (dielectric flux-density) that will electrically rupture the atmosphere at the

*From "The conductivity of the atmosphere at high voltages," by H. J. Ryan, in the Trans. of the A. I. E. E., Vol. XXIII., p. 101, 1904.

distance $d$ from the surface of the conductor having a radius $r$ measured in coulombs per square inch.

In a similar manner such an effect may be produced on a series of small cylinders separated by small air gaps when they are subjected to a difference of potential. Due allowance must be made if the cylinders have sharp or round corners of small radii, the influence of which will cause atmospheric rupture to occur at a lower potential than would be expected in the case of cylinders of that diameter.

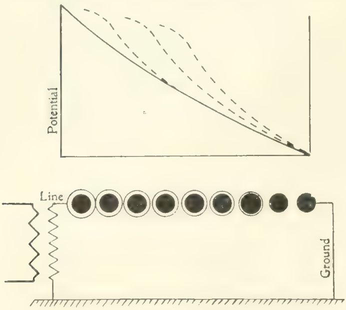



FIG. 3—CURVES SHOWING THE SHIFTING OF STRAIN AGAINST GROUND OVER A SERIES OF SMALL AIR GAPS SEPARATED BY METAL CYLINDERS AND ARRANGED AS SHOWN, WHEN THE POTENTIAL IS RAISED TO THE POINT OF BREAKDOWN

Fig. 3 represents a series of small air gaps between metal cylinders placed across the terminals of a transformer. If the potential of the circuit be raised sufficiently, the difference of potential between the cylinders and ground will cause the air immediately surrounding the first few cylinders on the line side to become ionized, enclosing the cylinders in an envelope of partially conducting gas. It will thus be seen that if the air gap be small, the corona, as it is sometimes called, will be of sufficient depth to bridge the gap. In so doing it will reduce the potential across the gap to practically zero. This condition is represented in Fig. 3 by the light circles surrounding the cylinders, As soon as the first cylinders are thus broken down the potential strain against the ground shifts its position, step by step, as indicated by the dotted curves. By slowly increasing the voltage, it will be caused to travel like a wave down the series until the point is reached where the remaining gaps have reached their breakdown voltage. A like

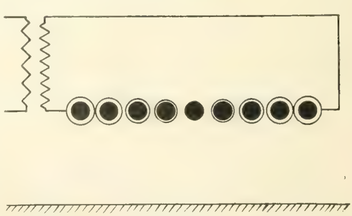


FIG. 4—DIAGRAM ILLUSTRATING THE CORONA EFFECT WHEN THE CIRCUIT IS UNGROUNDED

condition is produced when the circuit is ungrounded, but has its maximum effect at the end of the series gaps, dropping practically to zero at the middle point of the series as shown in Fig. 4. The starting of this effect is quite noticeable to the eye through the action of the cylinders on the line side. A continuous play of charging current may be seen at this point.

### GROUND SHIELDS

If the excessive difference of potential between the cylinders on the line end of the series and ground, is reduced or removed, the voltage-sustaining power of the gaps may be raised to practically their full value. It is possible to accomplish this by introducing a "ground shield" consisting of a thin metallic plate or parallel rods between the series of cylinders and the ground, in close proximity to them, well insulated from them and electrically connected to the line. The strain against the ground is transferred from the cylinders to the shield. The effect of shielding the cylinders when one side of the line is grounded, is represented by the curves in Fig. 5. The combination of strains across the gaps without the shield is represented by the potential gradient curve *A*. The slope of this curve shows a concentration of potential on the line gaps. When the shield is introduced the effect is to distribute the potential strain over a greater number of gaps as indicated by curve *B*, the ideal condition being represented by the straight line gradient *C*.

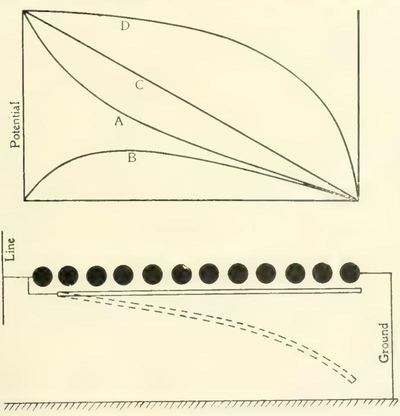


FIG. 5—CURVES SHOWING THE SHIELD ACTION

The dimensions and position of the shield, however, have much to do with the results obtained. If it is placed so as to cover all of the gaps of the multi-gap series, and parallel to them through-

out the full length, there will be a strain similar to the ground strain but of opposite value, caused by the difference of potential introduced between the gaps on the ground side of the arrester and the shield. Because of the greater capacity between these gaps and the shield, the difference of potential per gap will be even greater than that of the line gaps under the original conditions with no ground shield present. Curve *D* represents the potential gradient for these conditions To obtain the ideal gradient it is obviously necessary to so shape the ground shield as to eliminate this superimposed influence on the ground gaps. A ground shield properly modified to give the desired results is shown by the dotted lines in Fig. 5. It is quite evident, however, that a shield of this form would be difficult to insulate and would require more space than is practicable. A reasonably satisfactory compromise is made by reducing the length of the shield a proper amount and placing it in close proximity to the gaps. This arangement is shown in Fig. 6 and the resulting potential gradient is represented by curve *E*. The distribution of potential is practically uniform as indicated by the close approximation of this curve to the straight line gradient, curve *B*. Actual tests with a series of gaps and shields of different lengths arranged in this way are represented by the curve in Fig. 7.

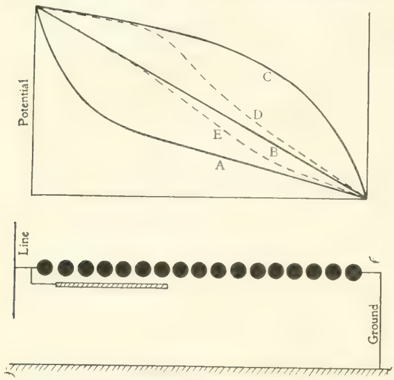



FIG. 6—CURVES SHOWING CLOSE APPROXIMATION TO IDEAL CONDITIONS OBTAINED BY THE USE OF A SHORT SHIELD AS SHOWN

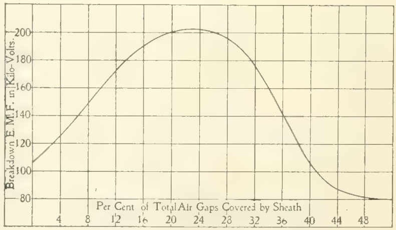



FIG. 7—CURVE SHOWING BREAKDOWN VOLTAGE WITH SHIELDS OF DIFFERENT RELATIVE LENGTHS

It will be noted that a shield covering about one-fourth of the gaps will increase the breakdown e.m.f. from about 100 000 to 200 000 volts. The counter-effect of a shield extending over the entire length of the multi-gap series which was noted above, is born out in this curve. The voltage across the total series increases to a maximum as the number of gaps shunted by the shield is increased, while by further lengthening the shield the total break-down voltage is correspondingly lowered. It is apparent then that for any given number of spark gaps there is also a particular suitable length of shield to give a maximum break-down potential.

The most advantageous ratios of shielded to total gaps for various voltages and multi-gap series, may be represented in the form of a curve similar to curve *C* in Fig. 1. This curve will approximate a straight line, which shows that the potential difference per gap is approximately the same whether the total multi-gap series be that suitable for 15 000 volts or for 70 000 volts. This difference of potential in actual figures is about 450 volts, whereas the breakdown per gap at the higher voltage with the shield omitted is only about 200 volts.

The above applies only to a series of air gaps when one end of the series is grounded. For ungrounded conditions when the strain is distributed as shown by the dotted line in Fig. 2, it will be quite evident that shields should be placed at both ends of the series to secure the best results. This condition, however, is one that is seldom encountered in practice.

From the foregoing it will be evident that the irregularities that have been referred to in connection with the operation of lightning arresters of the multi-gap type are actually due to different distances to points at ground potential in different cases. The effect of decreasing the distances between line gaps and nearby points that are at ground potential is simply to intensify the strain to ground and cause the arrester to discharge at a lower voltage.

The sudden grounding of a normally ungrounded transmission line gives rise to an especially unfavorable condition so far as the potential strain on the line gaps is concerned when no shield is present, for the full potential of the line is impressed upon the lightning arrester and the ground influence is consequently raised to a maximum.

By the use of ground shields the exact minimum break-down potential of lightning arresters for a given voltage may be determined before installation, thus obviating the necessity of calibration after the arresters have been installed.

# THE ENGINEER OF THE TWENTIETH CENTURY*

CHAS. F. SCOTT

GENTLEMEN:—It is significant that the response to this toast is assigned to the representative of the Engineers' Society of Western Pennsylvania. This society represents the engineers of Pittsburg, the city above all others preëminent in its industrial and engineering works in the country which is assuming the industrial supremacy of the world. The products of Pittsburg owe their inception to the inventions and designs of the engineer; under his supervision they are manufactured; and in turn they become the materials which other engineers employ in the construction of buildings, railroads and power plants throughout the whole world. This is the age of steel; Pittsburg furnishes the steel. This is the age of electricity; she produces the largest dynamos. The tonnage of Pittsburg's railways far exceeds that of New York City. The tonnage of the Pittsburg harbor, notwithstanding shallow bottoms and low bridges, approximates that of the New York harbor. Industrial Pittsburg! of the engineer! by the engineer! for the engineer!—typical of the present, significant of the future! Do you ask me to portray that future? I ask you to look back fifty years to the time when the first railroad bridge across the Allegheny, built against the protest of hack drivers and sympathetic citizens, brought together the track from Ohio and the track to Philadelphia; it brought them together, but it did not join them; for the state legislature had ordained that the gauges of the tracks should be different, in order to prevent domestic cars from wandering too far from home. Compare conditions then with those now. Note what the engineer has done since some of those present reached middle life. Who will venture to predict what we young men may see before we become old? It is with pride that I see how my own city—Smoky City of the Keystone state, the city of engineers and of industry—is growing in influence. A week ago a Philadelphia paper quoted a multi-millionaire thus: "Pittsburg instead of Wall street must be considered hereafter as the potent factor in the con-

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*Response to a toast at the twenty-fifth anniversary of the Engineers' Club of Philadelphia, December 6, 1902. Mr. Scott was at that time president of the Engineers' Society of Western Pennsylvania and also president of the American Institute of Electrical Engineers.

tinuation of our national prosperity." When money rates go up in Wall street and wage rates go up in Pittsburg simultaneously, it is the industrial thermometer which most truly indicates the real prosperity. Enter engineer; Exit speculator.

It is significant also that the response to this toast is assigned to the representative of the American Institute of Electrical Engineers. This organization represents the electrical engineers of America—the country above all others preëminent in electrical activity—at a time when its applications are making this the age of electricity.

Electrical work is seldom independent. It does not stand alone, complete in itself. Electricity is usually an instrument, a means to an end. It is not energy derived at first hand from electricity which enables the car to move and the crane to lift a weight. It is power derived from the engine, which happily can be transmitted by electric wires better than by shafts or ropes or belts. It is because electricity is primarily an agent, a means, that its applications have been so diversified, so extensive, and so far-reaching in their effects.

The great discovery of the nineteenth century was Co-operation, the effectiveness of concentration, the efficiency of largeness. Compare the old days of the hand-loom in the home, of the shoemaker at his bench, of the individual oil well and coal mine, of the small railroad and of the small factory—compare these with modern methods, pregnant as they are with unbounded possibilities—possibilities of good and possibilities of evil; of good, because the engineer has provided the means for doing the world's work far more efficiently; of evil, because the social, industrial, the commercial systems have not kept pace with the advance made by the engineer, but are still tainted with injustice and selfishness.

The tendencies of the nineteenth century projected into the future, reveal in dim outlines at least, the engineer of the twentieth century. He is to deal with large affairs in a large way. He is to be closely related to every department of modern life. He is to become a chief factor in adjusting and operating the intricate mechanism of a new civilization. He is to advance to administrative positions for which his knowledge and his training peculiarly fit him. Note present examples. At the head of the Pennsylvania Railroad, directing its vast affairs in the present and planning to meet the demands of the future, is an engineer surrounded by engineers—President Cassatt. At the head of the interests with which I am connected is a man, successful as organizer and manager and finan-

cier, a genius in his foresight, but first of all an engineer, George Westinghouse. Sound judgment, breadth of view, integrity of character, the ability to understand and to control men as well as matter, and to direct human forces as well as physical forces, are essential to the engineer of the future. A recent event which has aided in bringing America to preëminence is the victory of our Navy. A naval battle is a contest between fighting machines, and these are the products of the engineer. All honor, then, to the engineer, so fittingly represented here to-night by Admiral Melville.

Besides their new relations to others, there will be new relations of engineers among themselves. All that I have said so far emphasizes what we all know, namely, that the several branches of engineering are intimately interdependent and correlated. Take a single instance of large work, the extension of the Pennsylvania Railroad into New York City—the tunnels under the Hudson and East Rivers, the terminal facilities and the electrical equipment—and endeavor to name an important branch of engineering which is not essential to this undertaking. The work of the future demands co-operation, not clanishness—unity, not jealousy. Engineers must be specialists, therefore they must work together. The several branches of the profession have their individual interests; they have a larger common interest. As we marvel at what the engineer has done, as we attempt to picture what he may accomplish, do we realize the far-reaching responsibilities which confront us? Shall we rise to meet them? We gave to the world the steam engine, the steam vessel, the railroad, the telegraph and the cable, machinery, industrial processes, the electrical central station—the fundamental requisites which underlie co-operation. Is it not time that we apply to ourselves the great lesson of the last century? What organization stands before the world as representative of the engineering profession? In what way do engineers present themselves to other professions? A noted lawyer recently addressed the annual banquet of a local engineers' society containing members of national and international reputation. His remarks were based upon the idea that all engineers were co-ordinate with a common chainman, and they would have been positively insulting but for his air of blissful ignorance. A few years ago a gentleman of eminence, in addressing the American Society of Mechanical Engineers, advised its members not to join in a machinists' strike Has the engineer been accorded the recognition and the reward which are his due? In what way do engineers co-operate to advance their own

profession by mutual helpfulness and by undertaking measures which advance the efficiency and the usefulness of engineering work? There are national engineering organizations of various kinds—the civil engineers, the mining engineers, the mechanical engineers, the electrical engineers, the architects, the naval architects and marine engineers, the engineers in the Army and the Navy, and there are the chemists, the electro-chemists and others. In general each knows that other societies exist, and they are mutually respectful, but there is some suspicion here and there that the others are a little too exclusive or that they are a bit jealous. These are the murmurings of littleness, not of largeness.

The several engineering professions, like the constitutent states, have their representative bodies, their legislatures, but why should there not be an Engineering Congress as well? Why not a national representative body, to stand for the profession of engineering as a whole, to promote a harmonious co-operation which will strengthen each and elevate all?

An incident of the past year is an auspicious omen. Four great societies have co-operated; they have taken a step which will bring recognition to the deserving individual and credit to the engineering profession. They have founded a medal; and at a recent magnificent dinner they have announced the award of the first John Fritz medal to the venerable man who has just spoken, John Fritz himself. But not less significant than even the medal is the discovery that the societies can work together, and that by doing so they can accomplish worthy ends.

In the vision of the future may we not discern a reflection of the John Fritz medal in the larger life of the twentieth century engineer? Methinks I see in that reflection the outlines of a magnificent building, the Capitol of American Engineering. Into this home, situated in the metropolis of the nation, are gathered the great engineering societies from their scattered lodgings. Here is a great technical library; here are ample assembly halls and comfortable parlors; here are the headquarters of a score of lesser societies, restricted in their sccope, but affiliated in their work. I see all over the country innumerable local societies and engineering clubs, no longer isolated but joined together into one great combination. I see them affiliated with the national bodies of the several professions—sometimes as local chapters—altogether constituting one great union. There is individual freedom but general co-

operation. Representing all the engineering professions and supported by the great union of the national engineering societies, I see an Engineering Congress giving to engineers a rank consistent with the importance of their work, and increasing the efficiency of the inter-relations among its members. An eminent body, it is powerful in advancing the common interests of engineers, and it represents the engineering profession in its relation to other professions, to pure science, to education, to legislation, to public improvements and to the general welfare.

Years ago engineers were individuals of trivial consequence compared with men in the learned professions. Now they, too, form a profession of recognized importance. But as yet the national societies of this profession, which has made the nineteenth century an era in the world's history, which has provided the means for the production of unmeasured wealth, and which promises yet greater things for the future, have not even adequate homes of their own. Within the present week the Society of Mechanical Engineers, which has a little house of its own, found it so very little that it was forced to hold its meetings in a large room in a nearby tavern, although there were present men through whose work hundreds of millions have been added to the wealth of this country, and their present efforts are to increase the efficiency of the future. Is this right? Is it just?

But may not the fault lie somewhat with the engineers themselves? Have they fully recognized their own strength and importance? Have they shown a disposition to act together, to do large work in a large way? Have they given promise that they would use the enlarged facilities in such a way as to increase the efficiency of engineering work?

The men who are mastering the powers of nature will yet rise in the strength of united effort to meet the increasing responsibilities of the coming years. For it is theirs to build the foundation of the new civilization; it is theirs to establish that material prosperity which is the underlying condition of broader, higher and fuller life.

The end of engineering is usefulness; the characteristic of America is activity; the modern method is co-operation. As engineers of the twentieth century, let us be useful; let us be active: let us co-operate.

# DROP IN ALTERNATING-CURRENT CIRCUITS

CHAS. F. SCOTT AND CLARENCE P. FOWLER

IN a direct-current circuit the drop in voltage depends upon the current and the ohmic resistance. In an alternating-current circuit the total drop depends not only upon the current and the ohmic resistance, but also upon the reactance of the circuit and the power-factor of the load. The method of finding the drop under given conditions is set forth in an article by Mr. Mershon which appeared in the March issue of the JOURNAL. A modification of that method is here described in which the drop or "resistance volts" which would result were a direct current to flow through the circuit is first determined and then a "drop factor" is found by which the drop with direct current must be multiplied in order to obtain the drop produced by alternating current. The drop factor depends upon three things—(1) the ratio between the reactance volts and the resistance volts, (2) the power-factor of the load, and (3) the percentage value of the resistance volts.

The first of these quantities depends upon the size of wire, the distance between wires and the frequency. Table I gives the ratio of reactance volts to resistance volts for conditions which are most likely to occur. This table is readily deduced from the table in the article by Mr. Mershon.

The effect of the second element, the power-factor of the load is given in a Table II in which the drop-factors for various ratios of resistance volts to reactance volts and various power-factors are given. These have been determined from Mr. Mershon's chart, using a resistance e.m.f. equal to ten percent of the delivered e.m.f.

The third element, the percentage value of the resistance e.m.f. has a relatively small effect on the value of the drop-factor so that the values given, which are determined for a resistance e.m.f. of ten percent, may be accepted as practically correct for all resistance values not exceeding fifteen or twenty percent. The greatest discrepancy occurs when the ratio is high and power-factor is 100 percent.

In Table I the ratio of the reactance to the resistance is given for wire sizes ranging from No. 6. B. & S. gauge to 300 000 circ. mils, for 60 cycles and for separations between conductors, ranging from six to sixty inches. In the same table will be found ratios

TABLE I—OHMIC RESISTANCE AND APPROXIMATE RATIOS OF REACTANCE TO RESISTANCE

| Size of wire | Resistance | | Ratio of Reactance to Resistance for the distance between wires of | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | per mile of line | per 1000 ft. of line | 6″ | 9″ | 12″ | 18″ | 24″ | 36″ | 60″ |
| | | | **60 Cycles** | | | | | | |
| 300 000 c.m. | 0.365 | 0.069 | 2.10 | 2.40 | 2.60 | 2.90 | 3.05 | 3.30 | 3.65 |
| No. 0000 | 0.518 | 0.098 | 1.65 | 1.82 | 2.00 | 2.15 | 2.30 | 2.50 | 2.70 |
| 000 | 0.653 | 0.124 | 1.35 | 1.50 | 1.60 | 1.75 | 1.86 | 2.00 | 2.20 |
| 00 | 0.824 | 0.156 | 1.10 | 1.22 | 1.32 | 1.44 | 1.50 | 1.65 | 1.80 |
| 0 | 1.04 | 0.197 | 0.91 | 1.00 | 1.06 | 1.15 | 1.22 | 1.34 | 1.45 |
| 1 | 1.31 | 0.248 | 0.74 | 0.81 | 0.86 | 0.94 | 0.98 | 1.08 | 1.15 |
| 2 | 1.65 | 0.313 | 0.60 | 0.65 | 0.70 | 0.75 | 0.80 | 0.86 | 0.94 |
| 3 | 2.08 | 0.394 | 0.50 | 0.53 | 0.57 | 0.62 | 0.65 | 0.70 | 0.75 |
| 4 | 2.63 | 0.497 | 0.41 | 0.43 | 0.46 | 0.50 | 0.53 | 0.57 | 0.62 |
| 5 | 3.31 | 0.627 | 0.31 | 0.35 | 0.38 | 0.41 | 0.43 | 0.46 | 0.50 |
| 6 | 4.18 | 0.791 | 0.26 | 0.29 | 0.31 | 0.33 | 0.35 | 0.37 | 0.40 |
| | | | **40 Cycles** | | | | | | |
| 400 000 c. m. | 0.275 | 0.052 | 1.80 | 2.00 | 2.15 | 2.48 | 2.65 | 2.90 | 3.20 |
| 300 000 " | 0.365 | 0.069 | 1.42 | 1.60 | 1.74 | 1.91 | 2.03 | 2.20 | 2.44 |
| No. 0000 | 0.518 | 0.098 | 1.10 | 1 22 | 1.32 | 1.45 | 1.53 | 1.66 | 1.82 |
| 000 | 0.653 | 0.124 | 0.91 | 1.00 | 1.07 | 1.17 | 1.25 | 1.34 | 1.47 |
| 00 | 0.824 | 0.156 | 0.74 | 0 82 | 0.88 | 0.95 | 1.01 | 1.09 | 1.20 |
| 0 | 1.04 | 0.197 | 0.61 | 0.67 | 0.71 | 0.77 | 0.82 | 0.90 | 0.96 |
| 1 | 1.31 | 0.248 | 0.50 | 0.54 | 0.58 | 0.63 | 0.66 | 0 72 | 0.78 |
| 2 | 1.65 | 0.313 | 0.40 | 0.43 | 0.47 | 0.50 | 0.53 | 0.57 | 0.63 |
| 3 | 2.08 | 0.394 | 0.34 | 0.36 | 0.38 | 0.42 | 0.43 | 0.46 | 0.50 |
| 4 | 2.63 | 0.497 | 0.27 | 0.29 | 0.31 | 0.33 | 0.35 | 0.38 | 0.41 |
| 5 | 3.31 | 0.627 | 0.21 | 0.23 | 0.25 | 0.27 | 0.29 | 0.31 | 0.33 |
| 6 | 4.18 | 0.791 | 0.18 | 0.19 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 |
| | | | **25 Cycles** | | | | | | |
| 500 000 c.m. | 0.211 | 0.040 | 1.40 | 1.60 | 1.75 | 1.95 | 2.05 | 2.30 | 2 50 |
| 400 000 " | 0.275 | 0.052 | 1.15 | 1.25 | 1 35 | 1.55 | 1.65 | 1.80 | 1.98 |
| 300 000 " | 0.365 | 0.069 | 0.89 | 1.00 | 1.08 | 1.20 | 1.27 | 1.38 | 1.52 |
| No. 0000 | 0.518 | 0 098 | 0.69 | 0.76 | 0.84 | 0.90 | 0.96 | 1.04 | 1.12 |
| 000 | 0.653 | 0.124 | 0.56 | 0.63 | 0.67 | 0.73 | 0.78 | 0.84 | 0.92 |
| 00 | 0.824 | 0.156 | 0.46 | 0.51 | 0.55 | 0.60 | 0.63 | 0.68 | 0.75 |
| 0 | 1.04 | 0.197 | 0.38 | 0.42 | 0.44 | 0.48 | 0.51 | 0.56 | 0.60 |
| 1 | 1.31 | 0.248 | 0.31 | 0.34 | 0.36 | 0.39 | 0.41 | 0.45 | 0.48 |
| 2 | 1.65 | 0.313 | 0.25 | 0.27 | 0.29 | 0.31 | 0.33 | 0.36 | 0.39 |
| 3 | 2.08 | 0.394 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 | 0.29 | 0.31 |
| 4 | 2.63 | 0.497 | 0.17 | 0.18 | 0.19 | 0.21 | 0.22 | 0.24 | 0.26 |
| 5 | 3.31 | 0.627 | 0.13 | 0.15 | 0.16 | 0.17 | 0.18 | 0.19 | 0.21 |
| 6 | 4.18 | 0.791 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 |

NOTE—The resistance in the table is given per mile and per 1000 ft. of line; the length of wire is two miles and 2000 ft. respectively.

TABLE II—DROP-FACTORS WHEN RESISTANCE VOLTS ARE TEN PERCENT OF THE DELIVERED VOLTS

| Ratio of Reactance to Resistance | Drop-Factors for Power-Factors of— 100% | 95% | 90% | 85% | 80% | 70% | 60% | 40% | 20% |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 1.00 | 1.00 | 1.00 | 0.94 | 0.88 | 0.80 | 0.70 | 0.60 | 0.30 |
| 0.2 | 1.00 | 1.01 | 1.01 | 0.98 | 0.92 | 0.86 | 0.82 | 0.67 | 0.40 |
| 0.3 | 1.00 | 1.05 | 1.05 | 1.02 | 0.99 | 0.93 | 0.89 | 0.74 | 0.50 |
| 0.4 | 1.00 | 1.08 | 1.10 | 1.08 | 1.04 | 1.00 | 0.93 | 0.82 | 0.60 |
| 0.5 | 1.00 | 1.11 | 1.14 | 1.13 | 1.10 | 1.07 | 1.01 | 0.92 | 0.70 |
| 0.6 | 1.01 | 1.15 | 1.18 | 1.19 | 1.15 | 1.14 | 1.09 | 1.01 | 0.80 |
| 0.7 | 1.02 | 1.18 | 1.23 | 1.24 | 1.21 | 1.20 | 1.17 | 1.11 | 0.91 |
| 0.8 | 1.02 | 1.21 | 1.28 | 1.29 | 1.28 | 1.27 | 1.24 | 1.20 | 1.01 |
| 0.9 | 1.03 | 1.25 | 1.33 | 1.34 | 1.34 | 1.35 | 1.32 | 1.29 | 1.11 |
| 1.0 | 1.04 | 1.28 | 1.37 | 1.39 | 1.40 | 1.41 | 1.39 | 1.38 | 1.20 |
| 1.1 | 1.05 | 1.32 | 1.41 | 1.44 | 1.45 | 1.48 | 1.47 | 1.46 | 1.30 |
| 1.2 | 1.06 | 1.35 | 1.46 | 1.50 | 1.51 | 1.55 | 1.54 | 1.55 | 1.40 |
| 1.3 | 1.07 | 1.39 | 1.51 | 1.55 | 1.57 | 1.62 | 1.63 | 1.64 | 1.49 |
| 1.4 | 1.08 | 1.43 | 1.55 | 1.61 | 1.64 | 1.70 | 1.71 | 1.72 | 1.59 |
| 1.5 | 1.10 | 1.47 | 1.60 | 1.67 | 1.70 | 1.77 | 1.80 | 1.81 | 1.70 |
| 1.6 | 1.10 | 1.51 | 1.65 | 1.74 | 1.77 | 1.85 | 1.87 | 1.90 | 1.80 |
| 1.7 | 1.13 | 1.55 | 1.70 | 1.79 | 1.84 | 1.92 | 1.95 | 1.99 | 1.90 |
| 1.8 | 1.15 | 1.59 | 1.76 | 1.85 | 1.91 | 1.99 | 2.04 | 2.08 | 1.99 |
| 1.9 | 1.17 | 1.63 | 1.82 | 1.91 | 1.98 | 2.06 | 2.11 | 2.16 | 2.08 |
| 2.0 | 1.18 | 1.68 | 1.87 | 1.96 | 2.04 | 2.14 | 2.19 | 2.25 | 2.18 |
| 2.1 | 1.20 | 1.72 | 1.92 | 2.03 | 2.10 | 2.21 | 2.28 | 2.35 | 2.28 |
| 2.2 | 1.22 | 1.77 | 1.98 | 2.09 | 2.17 | 2.29 | 2.37 | 2.45 | 2.38 |
| 2.3 | 1.23 | 1.82 | 2.03 | 2.15 | 2.23 | 2.37 | 2.45 | 2.53 | 2.48 |
| 2.4 | 1.25 | 1.87 | 2.09 | 2.22 | 2.30 | 2.44 | 2.53 | 2.62 | 2.58 |
| 2.5 | 1.27 | 1.91 | 2.14 | 2.28 | 2.37 | 2.52 | 2.60 | 2.71 | 2.67 |
| 2.6 | 1.30 | 1.95 | 2.20 | 2.34 | 2.44 | 2.60 | 2.67 | 2.80 | 2.76 |
| 2.7 | 1.32 | 1.99 | 2.26 | 2.41 | 2.51 | 2.68 | 2.74 | 2.98 | 2.86 |
| 2.8 | 1.35 | 2.05 | 2.32 | 2.47 | 2.57 | 2.76 | 2.82 | 3.07 | 2.95 |
| 2.9 | 1.37 | 2.10 | 2.39 | 2.54 | 2.64 | 2.83 | 2.91 | 3.15 | 3.05 |
| 3.0 | 1.40 | 2.15 | 2.45 | 2.60 | 2.72 | 2.90 | 3.00 | 3.23 | 3.15 |
| 3.1 | 1.42 | 2.20 | 2.51 | 2.66 | 2.80 | 2.97 | 3.10 | 3.31 | 3.25 |
| 3.2 | 1.45 | 2.26 | 2.57 | 2.73 | 2.87 | 3.05 | 3.20 | 3.39 | 3.35 |
| 3.3 | 1.48 | 2.31 | 2.63 | 2.80 | 2.93 | 3.12 | 3.30 | 3.47 | 3.45 |
| 3.4 | 1.51 | 2.36 | 2.69 | 2.87 | 3.00 | 3.20 | 3.39 | 3,56 | 3.54 |
| 3.5 | 1.53 | 2.42 | 2.74 | 2.94 | 3.08 | 3.27 | 3.48 | 3.65 | 3.63 |
| 3.6 | 1.57 | 2.47 | 2.80 | 3.00 | 3.15 | 3.35 | 3.56 | 3.75 | 3.72 |
| 3.7 | 1.60 | 2.52 | 2.86 | 3.07 | 3.23 | 3.43 | 3.65 | 3.85 | 3.80 |

of reactance to resistance for sizes of wire ranging from No. 6 B. & S. to 400 000 circ. mils for 40 cycles, and from No. 6 B. & S. to 500 000 circ. mils for 25 cycles, both of these covering the same range of wire separations as in the case of 60 cycles. Table I also contains ohmic resistance per thousand feet of line and per mile of line for the various sizes of wire tabulated.

Table II contains various ratios of reactance to resistance which cover approximately the same range as those which appear in Table I. Opposite the ratios in this table are given the drop-factors corresponding to power-factors from 100 percent down to 20 percent. The drop-factors are determined for a value of the resistance volts equal to ten percent of the delivered e.m.f.

To illustrate the use of the Tables I and II, two examples are here worked out and others with varying conditions have been calculated, the data and results of which are given in Table III.

### EXAMPLE I—SINGLE PHASE

From Table III it will be seen that in example *1* it is desired to deliver 50 real kilowatts at 1 000 volts and 100 percent power-factor over a single-phase line 2 000 feet long composed of two No. 4 B. & S. gauge copper wires, the frequency being 60 cycyles and the conductors having a separation of 12 inches.

*Ohmic Volts*—The first step is the determination of the apparent kilowatts, which is obtained by dividing the real kilowatts by the power-factor, or $50 \div 1.00 = 50$ apparent kilowatts, which results in a single-phase current of $50\,000 \div 1\,000 = 50$ amperes. In Table I, the resistance volts per 1 000 feet of line for No. 4 wire are given as 0.497, hence the total resistance volts $= 2 \times 50 \times 0.497 = 49.7$ volts.

*Total Drop*—Referring again to Table 1, it may be seen that the ratio of reactance to resistance for No. 4 B. & S. wire with 12-inch spacing at 60 cycles is 0.46. In Table II 0.50 is the ratio which is nearest to 0.46, and the coresponding drop-factor for 100 percent power-factor is 1.00. So that the total drop in volts is $49.7 \times 1.00 =$ 49.7 volts, or expressed as percent of delivered e.m.f. $= 4.97$ percent. The impressed e.m.f. would be $1\,000 + 49.7 = 1\,049.7$ volts. In this case, as the drop factor is 1.00, the total drop is practically equal to the ohmic drop.

The method of working out the next three examples in Table III is similar to the above, all of these being single-phase circuits, with changes in the various other data.

TABLE III—EXAMPLES OF DROP CALCULATIONS IN ALTERNATING-CURRENT CIRCUITS

| Example | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Given** | | | | | | | | | | | | | | |
| E.m.f. delivered | 1 000 | 2 000 | 6 000 | 10 000 | 20 000 | 15 000 | 40 000 | 30 000 | 25 000 | 400 | 200 | 200 | 400 | 400 |
| Kw delivered (real power) | 50 | 75 | 400 | 500 | 1 500 | 1 200 | 10 000 | 6 000 | 4 000 | 60 | 5 | 10 | 75 | 100 |
| Power-Factor (per cent) | 100 | 95 | 90 | 80 | 60 | 70 | 85 | 80 | 80 | 40 | 20 | 90 | 95 | 80 |
| Number of Phases | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Frequency (cycles per second) | 60 | 60 | 60 | 60 | 25 | 25 | 25 | 25 | 60 | 60 | 60 | 60 | 25 | 25 |
| Size of Wire | 4 | 4 | 2 | 3 | 0 | 1 | 300 m.c.m. | 0000 | 000 | 00 | 5 | 6 | 0 | 0000 |
| Distance between Wires (inches) | 12 | 18 | 24 | 24 | 36 | 36 | 60 | 60 | 60 | 9 | 6 | 18 | 12 | 24 |
| Length of circuit: Miles | ..... | ..... | 5 | 10 | 25 | 12 | 40 | 30 | 20 | ..... | ..... | ..... | ..... | ..... |
| Length of circuit: Feet | 2 000 | 5 000 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 000 | 500 | 750 | 1 500 | 2 000 |
| **Ohmic Volts** | | | | | | | | | | | | | | |
| Apparent Kw | 50 | 79 | 445 | 625 | 2 500 | 1 720 | 11 700 | 7 500 | 5 000 | 150 | 25 | 11 | 79 | 125 |
| ½ apparent Kw for three phases | ..... | ..... | ..... | ..... | 1 250 | 860 | 5 850 | 3 750 | 2 500 | 75 | 12.5 | 5.5 | 38.5 | 62.5 |
| Amperes | 50 | 39.5 | 74 | 62.5 | 62.5 | 57 | 147 | 125 | 100 | 188 | 62.5 | 27.5 | 97. | 157. |
| Resistance volts for unit length: one mile of line | ..... | ..... | 1.65 | 2.08 | 1.04 | 1.31 | 0.365 | 0.518 | 0.653 | ..... | ..... | ..... | ..... | ..... |
| Resistance volts for unit length: 1000 feet of line | 0.497 | 0.497 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.156 | 0.627 | 0.791 | 0.197 | 0.098 |
| Resistance volts for given distance and current | 49.7 | 99. | 610 | 1 300 | 1 625 | 900 | 2 150 | 1 950 | 1 306 | 29.3 | 19.6 | 16.3 | 28.5 | 30.5 |
| **Total Drop** | | | | | | | | | | | | | | |
| Ratio of Reactance to Resistance (Table I) | 0.46 | 0.50 | 0.80 | 0.65 | 0.56 | 0.45 | 1.52 | 1.12 | 2.20 | 1.22 | 0.31 | 0.33 | 0.44 | 0.96 |
| Drop-Factor (Table II) | 1.00 | 1.11 | 1.28 | 1.15 | 1.09 | 1.00 | 1.67 | 1.45 | 2.17 | 1.55 | 0.51 | 1.05 | 1.08 | 1.40 |
| Total drop, volts | 49.7 | 109.9 | 781 | 1 495 | 1 771 | 900 | 3 580 | 2 830 | 2 830 | 45.5 | 9.99 | 17.1 | 30.8 | 42.7 |
| Total drop in % of delivered e.m.f. | 4.97 | 5.5 | 13.0 | 14.95 | 8.85 | 6.00 | 8.95 | 9.45 | 11.3 | 11.3 | 4.99 | 8.5 | 7.7 | 10.6 |
| Impressed e.m.f. in volts | 1049.7 | 2109.9 | 6 781 | 11 495 | 21 771 | 15 900 | 43 580 | 32 830 | 27 830 | 445.5 | 209.99 | 217.1 | 430.8 | 442.7 |

EXAMPLE 5—THREE PHASE

Example 5 is typical of three-phase circuit calculations. In this example, it is required to deliver 1 500 real kilowatts at 20 000 volts and 60 per cent power-factor over a 25-mile three-phase line composed of three No. 0 B. & S. copper wires, having a separation of 36 inches, the frequency being 25 cycles.

*Ohmic Volts*—The real kilowatts being 1 500 and power-factor 60 percent, the apparent kilowatts=1 500 : 0.60=2 500 kilowatts. As the circuit is three-phase, the apparent kilowatts to be considered

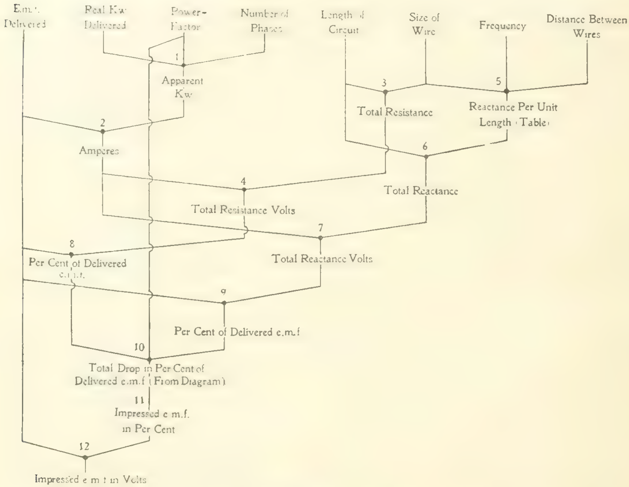


FIG. 1—DIAGRAM INDICATING STEPS TAKEN IN CALCULATING LINE DROP BY THE METHOD GIVEN IN MR. MERSHON'S ARTICLE [SEE MARCH ISSUE]

The eight quantities necessary for calculating drop are given at the top of the diagram.

in this example are one-half of the total apparent kilowatts, or 2 500÷2=1 250 kilowatts, which gives a current of 1 250 000÷20 000=62.5 amperes. This is the current in an equivalent single-phase circuit delivering half the output with the same percent loss and drop as occur in the three-phase circuit.

From Table I, the resistance volts per mile of line for No. 0 B. & S. copper wire are 1.04 volts, hence the total resistance volts=$25\times62.5\times1.04$=1 625 volts.

*Total Drop*—In Table I, the ratio of the reactance to the resistance for No. 0 B. & S. wire with 36-inch spacing at 25 cycles= 0.56. In Table II, the nearest ratio to 0.56 is 0.60 and the drop-factor corresponding to this ratio for 60 percent power-factor is 1.09. Hence, the total drop=1 625×1.09=1 771 volts, or expressed in percent of delivered e.m.f.=8.85 percent. The impressed e.m.f. would be 20 000+1 771=21 771 volts.

STEPS TAKEN IN CALCULATING DROP

A comparison of the method of determining the drop in an alternating-current circuit, as outlined in Mr. Mershon's article, in the March issue and the method given in the present article is

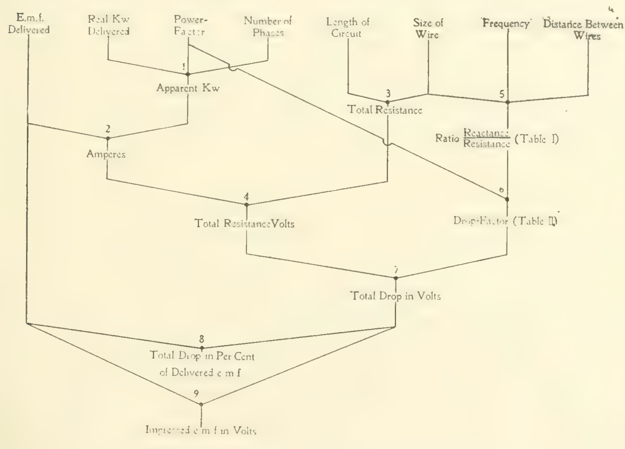


FIG. 2—DIAGRAM INDICATING STEPS TAKEN IN CALCULATING LINE DROP BY THE METHOD GIVEN IN THE PRESENT ARTICLE

The eight quantities necessary for calculating drop are given at the top of the diagram.

shown in the two diagrams shown in Figs. 1 and 2. In these diagrams, which are self-explanatory, the various steps in the calculations are numbered in the order in which they occur.

# THE STANDARDIZING LABORATORY—V.

## MEASUREMENTS INVOLVING THE USE OF SERIES TRANSFORMERS

H. B. TAYLOR

SERIES transformers, when judiciously used, are valuable adjuncts to instruments for alternating-current measurements. Like other apparatus, they have limitations which are sometimes overlooked. They are, perhaps, more subject to misuse than the instruments themselves, for the reason that, excepting their maximum carrying capacity, there is nothing about them to indicate their limits of usefulness. A thorough study of these simple-looking objects presents some very complex problems, but it is the intention to make note in this article of only the more important factors which affect the accuracy of measurements made with instruments connected to the secondaries of series transformers, without attempting to explain the reasons for any of the phenomena.

### RATIO

As the series transformer is used solely for the purpose of producing a current having a known ratio to the current to be measured, a knowledge of the conditions which affect ratio should be the first requsite in putting them into service. Ratios vary a great deal more in some transformers than in others, but it is safe to say that no transformer gives a constant ratio at all loads from its full rated capacity to an extremely small fraction thereof. The general statements here given apply to series transformers as a class. The magnitude of the errors in any given case depend on details of design and materials.

The ratio in the neighborhood of full load is less subject to error than that at lower loads. The chief cause of error in ratio is the employment of an impedance in the secondary circuit higher than that for which the transformer was designed. In this particular, the effect of the extra impedance is just opposite to what it is often assumed to be. At low loads the secondary e.m.f. required is, of course, lower than at high loads if the secondary impedance be constant. It might seem therefore that an increased impedance at the low loads would have no undesirable effect. The fact is that a given change, within reasonable limits, of secondary impedance, has a greater effect on the ratio at low loads than at high

ones. Naturally, if the increase is carried to excess so that the core becomes saturated at the high loads, the reverse will be true, but that is not likely to be a practical condition such as would be met in changing from one type of meter to another or in putting two or three different kinds of meters in series on the same transformer.

Increasing the impedance of the secondary circuit causes a decrease in the secondary current resulting from a given current in the primary. Since the proportional decrease is greater at the low loads than at the high ones, as stated above, it follows that if the secondary impedance be increased at the low loads only, by exchanging an instrument used at the high loads for one which will give a more legible reading at the low ones, the discrepancy in ratio is likely to be large. The low reading instrument invariably has a higher impedance than the one of larger capacity and this additional impedance is introduced into the circuit while making the very measurements which will be most influenced by it. This point can not be too strongly emphasized, because it is so easy to fall into the error of measuring the currents at different loads with different ammeters in the secondary circuit. Few alternating-current ammeters can be read with accuracy at loads below thirty per cent of their full-scale readings. It is not unnatural, then, to change ammeters two or three times in taking readings on a wide range of currents.

Integrating wattmeters which have a range of accurate calibration from two to one hundred and fifty per cent of their rated loads are used extensively in connection with series transformers. It is therefore necessary that the performance of the transformer throughout the same range be known. To measure the ratio with ammeters, keeping the readings always above one-fourth scale, would necessitate at least three changes even if it is assumed that ammeters of the exact capacities required are available. Since alternating-current ammeters of the same type have impedances approximately in reverse proportion to the squares of their capacities, it is evident that the secondary impedance could easily be sixteen times as great at the low readings as at the high ones.

Ratio curves so determined are useful in the test room if used in connection with the instruments and transformers for which they were made, or their counterparts. If a smooth curve is made and applied indiscriminately to a certain transformer, it is worse than useless, for it may lead to the placing of confidence in results that

are in greater error than would have resulted if there had been no attempt to correct for error in ratio.

### PRACTICAL APPLICATIONS

Fortunately, the service condition in which it is most important that the range of accurate ratio shall be long is the one in which it actually is longest. Wattmeters, especially integrating wattmeters, require accuracy in the transformer over a much wider range than is necessary for other instruments. As the impedance of the series coil of a wattmeter is lower than that of an ammeter of the same capacity, the ratio of transformation is correct over a wider range. Apparently, the nearer the approach to a short-circuited secondary, the wider is the range of loads at which the ratio is constant. Readings of alternating-current ammeters at currents below ten per cent of full load are so low on the scale as to be unreliable. Provided, then, that the correct value of current is supplied at the higher loads, it is of no particular advantage to have the current below ten per cent of full load very close to the correct value.

### GENERAL NOTES

Questions sometimes arise as to whether the phase of the secondary current is in exact opposition to that of the primary current, that is, whether wattmeters used with series transformers are as accurate at low power-factors as those without. That there can be no serious error is shown by the fact that registration of an induction wattmeter on lamp load usually indicates slightly more than unity power-factor if the ratio of transformation as shown by ammeters is assumed to be correct. The slight excess of current is due to the low impedance of the wattmeter series coil, but any appreciable displacement in phase of secondary current would counteract it. This conclusion has been verified by check readings at low power-factors, including zero power-factor.

Other things being equal, a transformer containing a liberal amount of iron gives a more stable ratio than one containing only a small amount. Low tension transformers with compact, low resistance windings are more reliable than those for high tension service.

The ratio of a series transformer is correct in one direction only. For example, one which is designed to give five amperes secondary current with 20 amperes primary current, or a ratio of four to one, will not produce satisfactory results when connected to the

same ammeter in the reverse order for measuring currents of 1.25 ampere or less, that is in the ratio of one to four. It is true that if the heavy-current terminals are short-circuited, an alternating current passed through the low-current coil will induce a comparatively heavy current in the other side, but the ratio is not accurate enough for the purpose of measurement.

### FORM OF CURVE

Ratio curves which are intended to show the performance of a transformer rather than for use in making corrections on a set

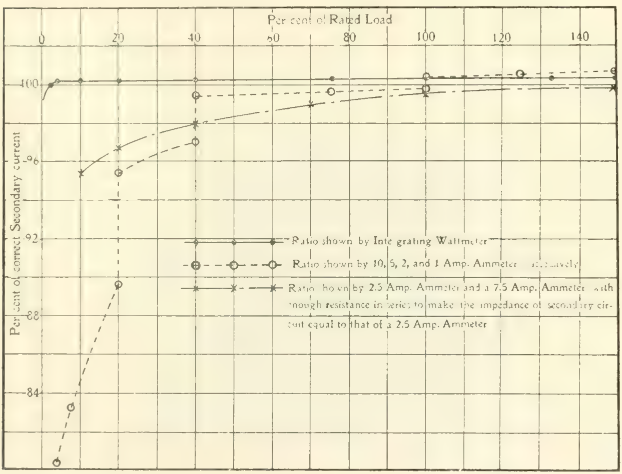


FIG. 1—RATIOS OF A SERIES TRANSFORMER AS MEASURED WITH DIFFERENT INSTRUMENTS

of readings may conveniently be plotted between percent of rated load and ratio of actual to correct secondary current. By correct secondary current is meant the current which would flow in the secondary if there were no ratio error. Obviously the performance curve of a perfect transformer platted in that way would be a straight horizontal line from the ordinate corresponding to unity. The scale can be large enough to show clearly errors of a small fraction of one per cent without making the curve of unwieldy size. Fig. 1 shows some typical ratio curves, the three curves being for

the same transformer under different conditions. The full line curve shows the ratios when the series coil of an integrating wattmeter is the only secondary load. The dotted line curve was taken with four different ammeters in the secondary. Currents from 150 to 100 per cent load were measured with a ten ampere meter; from 100 to 40 per cent with a five ampere meter; from 40 to 20 per cent with a two ampere meter, and from 20 to four per cent on a one ampere meter. The dot and dash curve shows the result of a test in which the secondary impedance was constant throughout all of the readings and was equal to that of a 2.5 ampere meter of the type used for the dotted line curve.

### TRANSFORMERS WITHOUT PERMANENT PRIMARY

A convenient kind of series transformer for use in testing is one without a permanent primary winding. The core and sec-

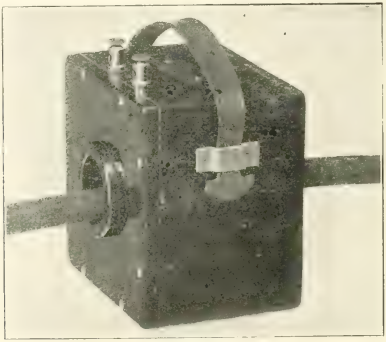

FIG. 2

ondary coil are arranged so that a conductor passed one or more times through a hole in the middle of the core acts as the primary. When a transformer of that description is used the number of primary turns can be made to suit the current to be measured so that the reading of the ammeter in the secondary will be within the best part of its range. Each time the primary conductor passes through the hole in the center counts one turn. The secondary current due to a given primary current is entirely independent of the direction taken by the conductor after it passes through the transformer. It is also independent of the position with reference to the iron core, whether passing through the middle or to one side of the hole.

Figs. 2 and 3 show two views of a transformer of this type. The arrangement of cable as in Fig. 2 corresponds to the connection of a bus-bar or other circuit with distant return. Fig. 3 shows the same transformer with the cable in an assumed position. By actual test it has been shown that a given primary current produces exactly the same deflection of secondary ammeter whether the primary conductor is arranged as shown in the first or in the second view. Tests also verify the theory that a certain number of ampere-turns in the primary will give a certain reading whether the primary consists of one turn carrying a heavy current or a large number of turns carrying a small current. This feature is useful in extending the range of a standard alternating-current ammeter. For instance, it may be necessary to measure accurately an alternating current of 1 000 or 2 000 amperes. Reliable alternating-current standards of that capacity are rare, but if a suitable standard of

FIG. 3

lower capacity and a bus-bar type transformer with ammeter are at hand, the transformer and ammeter, considered as a unit, can be calibrated accurately by comparison with the standard when the conductor is passed through the transformer a comparatively large number of times. Reducing the number of turns permits the measurement of currents above the capacity of the standard with a degree of accuracy almost equal to that of a direct comparison with it.

SECONDARY MUST BE KEPT CLOSED

Whenever series transformers are included in a circuit it is

important for several reasons to keep the secondary circuit closed. Apart from considerations of personal danger from the high secondary e.m.f. at open circuit and of possible damage to the transformer itself by overworking its iron, there is a probability of overloading other apparatus in the circuit if the current or e.m.f. of the line are adjusted before closing the secondary. The impedance of the primary is dependent upon the impedance of the secondary. If the latter is low, the e.m.f. across the former at full load will be very small. With open secondary the primary impedance would in some instances be such a large portion of the total impedance in the circuit that an excessive current would flow at the instant of closing the secondary, thereby cutting out the primary impedance.

INTERCHANGEABILITY

It is by no means intended to convey the idea that instruments used with series transformers can not be interchangeable. If the instruments and the transformer are made for the purpose of being used in that way, each piece can be tested to make sure that its performance will be the same as that of any other similar piece under all conditions. It is not in using transformers as the designer expected them to be used that errors are likely to occur, but in connecting them to instruments or combinations of instruments entirely different from those for which they were designed.

THE

# ELECTRIC JOURNAL

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**Evolution of Tool Steel**

The mid-November number of the "Proceedings of the American Institute of Mechanical Engineers" was devoted entirely to the classical paper by the president of the organization, Mr. F. W. Taylor, on "The Art of Cutting Metals."

The article by Mr. E. R. Norris on "High-Speed Steel Tools" in the present issue of the JOURNAL is based mainly on this paper, and in it are pointed out some of the more important features connected with the manufacture and use of this class of tools. As a prefatory, a few words on the evolution of steel for cutting tools may be of interest.

Until a comparatively recent period, steel for cutting tools had been made in the same general way. In the original process, as far as now known, refined iron, that is, iron with most of the impurities removed, was placed in a clay crucible with wood and green leaves. The crucible was then inserted in an oven where it was subjected to a very high temperature until the metal was reduced to the molten state, a certain amount of carbon being absorbed in the interval.

A modification of this process consisted in placing the refined iron, together with charcoal, in a furnace where, upon the application of the proper degree of heat, the iron became more or less impregnated by the carbon, according to the length of time the heating was continued.

The resulting product in each case was a steel of varying quality depending upon the percentage of carbon taken up and the uniformity of its distribution throughout the metal.

As the art of making steel developed, various improvements were made in the details of manufacture; but no radical changes may be considered to have been introduced until 1750, when Benjamin Huntsman, of Sheffield, England, found that, by remelting steel made according to the second method, its quality became more nearly homogeneous. This discovery of a process for manufacturing steel of a uniform quality gave a great impetus to the steel

industry and marked the beginning of a development of modern tool steels.

In 1868 Robert Mushet, of Coleford, England, who had been experimenting with a view to determining the effect of various elements upon the quality of steel when introduced into the crucible, produced a tungsten steel which was much superior in certain respects to the carbon steels hitherto used in the manufacture of cutting tools. This was an embryonic form of high-speed steel, but its value as such was not fully appreciated and its use was confined principally to the cutting of very hard metals. It may, therefore, be said to have supplemented and not replaced carbon steels.

No further important advance in the development of steels for cutting tools was made until 1898-1900 when Messrs. Taylor and White, of Philadelphia, announced the discovery of their process whereby "tools made from chromium-tungsten steels when heated to the melting point would do from two to four times as much work as other tools." The importance of this discovery was immediately recognized on all sides and in consequence the commercial development of high-speed steels followed rapidly.

The article by Mr. Norris gives in outline the situation to-day with regard to high-speed steel tools. Whether we are only at the beginning of their development it is impossible to foretell, but as the present state of the art has been reached without many of the aids which science is now able to place at its disposal it seems only reasonable to believe that further discoveries will be announced as time goes on.

The term "revolutionary" has been so indiscriminately applied to every advance over accepted standards as to have almost lost its significance; it is, however, certainly not misapplied when used to designate the changes made necessary in machine shop practice by the introduction of high-speed steels for cutting tools. Machine shops, large and small, where not already provided with machines suitable for using high-speed steel tools, are undergoing rearrangement of plant or alteration of equipment to admit of their use. As machines radically different in design and of more substantial build are required as well as heavier structural work and foundations, together with changes in the power supply, it will be seen how vitally the interests of all those engaged in the engineering industries are affected and how essential it is, therefore, to have at least a general knowledge of the subject.

C. B. Auel

**Progress in Prime Movers**

The readers of the Journal are to be congratulated upon the admirable article of Mr. Sniffin, vice president of the Machine Company, which appears in this issue, giving a brief history of the Machine Company. It covers more than its title implies, for a very appropriate sub-title might have been "A History of Progress in Prime Movers During the Last Twenty Years." Progress has been so rapid along many lines in recent years that those of us who take part in it have become accustomed to this accelerated pace and are prone to overlook the tremendous significance of what is occurring around us. It certainly is a remarkable growth in the progress of a company when the maximum size of its unit of product changes from about 500 horse power to about 15 000 horse power, as a number of the large turbines under construction will be. A fact which Mr. Sniffin emphasizes, and which is a matter of pride to every man connected with any Westinghouse industry, is the progressive spirit which dominates affairs. As shown by his article, the Machine Company was the pioneer in both the steam turbine and the gas engine. As we know, the other members of the Westinghouse group have also been pioneers in their lines, and this sustained effort to produce the best of its kind, that is, the most economical and most efficient in every line of work, is a valuable stimulus to every Westinghouse employe.

W. M. McFarland

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**Commutation and Direct-Current Design**

Applied science is now dependent more on local conditions than on the understanding of underlying principles. A few years ago nothing would have been a greater joy to an American engineer than the opportunity of criticising a paper by an English or Continental engineer or vice versa.

To the designer, the world has now become practically one, and in principles there is very little difference between Mr. Walker's article on "Problems in Commutation" in this issue of the Journal and one by an American engineer on the same subject. Mr. Walker's article is intended primarily for the beginner. He first points out the necessity of having good contact between brush and commutator and the mechanical difficulty in obtaining it. He then shows the electrical difficulties connected with commutation and explains the advantage of high resistance brushes, brush shifting,

a strong field, low permeability in the pole corners, commutating poles and short-chord winding. The paper closes with a list of causes to be looked for if a machine fails to commutate perfectly and in a foot note shows how to calculate the number of ampere-turns by which the auxiliary field coil should exceed the armature.

Two points in his paper call for comment. One is his reference to the inductor effect, where sparking is caused by the change in the number of teeth under a pole. This change in magnetic permeability will cause a change in the voltage of the machine. The amount of this change, however, will be slight and it will be of such high frequency that it can not be noticed. This flux, from the poles, is surrounded by the coil undergoing commutation. The change in flux will set up an alternating voltage in the short-circuited coil. This alternating voltage might be sufficient to cause poor commutation, but we would be more apt to look for the trouble as due to another cause. If the number of slots under the pole is so small as to cause a change in the magnetic permeability of the circuit, there is probably a great number of coils in each slot and a very small number of slots in the neutral space. Consequently each coil will be commutated in a different magnetic position, some in a very weak reversing field and some in a very strong reversing field. Good commutation would, in this case, be impossible and would be helped only by the remedy Mr. Walker gives, namely, "beveling the poles so as to give a more even magnetic fringe."

The other point to which we wish to refer is the strength of the main field with reference to the armature. He says the main field should have two or two and one-half times as many ampere-turns as the armature. Most American engineers seem to consider that while there are some good reasons for employing such a strong field it is, in general, stronger than necessary. Practically all designers, however, stick religiously to the rule that the field ampere-turns must exceed the armature ampere-turns by at least a certain percent, and the stronger the field the better are the commutating conditions. Neglect of this rule very generally brings a man into trouble, and yet practically every designer will admit that, in theory, it is wrong. It mistakes a cause for an effect. As the current flows in the armature coils it causes a flux around the coil. It is the cutting of this flux by the commutated coil that causes the trouble in commutation. True the flux is caused by the armature turns, but it is the flux and not the ampere-turns which cause a machine to spark. This flux is annulled by the flux from the

field. This field flux is caused by ampere-turns, but it is the field flux, not ampere-turns, which annuls the trouble. It should be possible to design a machine with a small number of field ampere-turns and at the same time with the air-gap and pole face arranged to give a field flux distribution that will annul the armature flux as perfectly as is done in our ordinary machines. That the ratio of armature ampere-turns to field ampere-turns is not a dominant factor is shown in the fact that some machines may be made to commutate better by decreasing the air-gap or lengthening the pole horns, thus decreasing the field ampere-turns.

J. N. Dodd

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**Engineering Societies Building Dedication**

"The whole occasion was to me most delightful. I think that the simple dignity and perfect taste of the program and of all the speeches must have impressed very strongly anybody who was not familiar with the way engineers can do things of that sort." In this manner a guest characterizes the dedicatory exercises of the new building of the Engineering Societies, the gift of Mr. Carnegie.

The dominant sentiment the first day was one of dignity and solemnity; interest centered in what Mr. Carnegie said. The second day congratulations were received, cordial and earnest, from sister societies and institutions at home and abroad.

The sentiment which pervaded the occasion was not merely one of satisfaction on the completion of a handsome building, but one of hope and confidence that it marks an important event in the new movement for the larger life of the engineer. Engineering is no longer an avocation; it is a profession.

Many of the addresses, notably the one by President Hadley on "Professional Ideals of the Twentieth Century," and those of the presidents of the societies will give ideas and inspiration to the younger members of the profession. They give the broader views of engineering work, views which the young man cannot afford to overlook if he aspires to eminence in his profession.

The young engineer may seriously consider whether he can afford not to have part in this new activity. Membership in a society may mean more than a subscription to its transactions. It brings new associations, new interests and the inspiration which comes from co-operation with one's fellows in a progressive movement.

Chas. F. Scott

# HIGH-SPEED STEEL TOOLS

E. R. NORRIS

MR. F. W. TAYLOR, president of the American Society of Mechanical Engineers, recently read a paper before that body on "The Art of Cutting Metals," in which were described at length the results of investigations made by himself and others associated with him. Experiments extending over a period of many years had been carried out with the view of determining the proper heat treatment of cutting tools, their shapes, angles, feeds, cutting speeds, etc. During these experiments, it was discovered that Mushet and other self-hardening tools, which had been previously looked upon as suitable only for cutting hard metals, could be used with even greater effect upon soft metals. This was followed by the discovery that by flowing water freely upon the chip and upon the nose of self-hardening tools, a much higher cutting speed could be employed. Still later it was found that tools made of chromium-tungsten steel, which had been heated close to the melting point during treatment, could be operated at even higher speeds and coarser feeds, thus giving a further advantage over other tools in the amount of work performed. Increased output is accompanied by a much higher temperature in the tool and the ability to stand up to the work under these conditions may be said to be a characteristic of all high-speed tools. This discovery of the properties of chromium-tungsten steel directed the attention of other investigators to the subject, and their labors have resulted in the production of many similar varieties of high-speed tool steels.

Steels of this class may, with a few exceptions, be grouped as follows:

A — Carbon — chromium — tungsten
B — Carbon — chromium — molybdenum
C — Carbon — chromium — molybdenum — tungsten
D — Carbon — tungsten — nickel

Considerable variation exists in the composition of these steels particularly in regard to the quantity of each of the principal elements entering into them. One of the best known American tools contains:

| | |
|---|---|
| Carbon. . . . . . . . . . . . . . . . . . . | 0.600 percent |
| Manganese. . . . . . . . . . . . . . . . | trace |

| | | |
|---|---|---|
| Silicon | 0.108 | percent |
| Phosphorus | 0.054 | " |
| Tungsten | 18.530 | " |
| Chromium | 2.950 | " |
| Sulphur | 0.008 | " |

Mr. Taylor recommends as the outcome of his latest experiments:

| | | |
|---|---|---|
| Carbon | 0.674 | percent |
| Manganese | 0.110 | " |
| Silicon | 0.043 | " |
| Phosphorus | ——— | " |
| Tungsten | 18.190 | " |
| Chromium | 5.470 | " |
| Sulphur | ——— | " |
| Vanadium | 0.290 | " |

All of these elements perform certain useful functions with the exceptions of sulphur and phosphorus which are termed impurities and which should, therefore, be reduced to the lowest practical amount.

THE MAKING OF THE TOOL

M. Le Chatelier, in a paper entitled "Rapid Steel for Tools," in the "Bulletin de la Societe D'Encouragement pour L'Industrie Nationale," states in effect that steel undergoes a change of nature between 700 and 800 degrees C. In heating, this occurs above 750 degrees C., the steel becoming hardened. In cooling, the return to the original or softened condition takes place below 750 degrees C. Experiments made by later investigators have proved the range of temperature fixed upon by M. Le Chatelier to be slightly inaccurate, the limits extending rather above and below the figures given by him. The points at which this transformation takes place are known as the "critical points" or "points of recalescence." By the introduction of various elements like chromium, tungsten, molybdenum, manganese, etc., the time required for the steel to pass from one condition to the other may be considerably retarded. The value of chromium for retarding this change from hardening to softening carbon has recently been questioned by Prof. H. C. H. Carpenter, who asserts that chromium has no tendency in this direction, but, on the contrary, actually hastens the change.

In the making of tools from carbon steels for ordinary work,

the material, on account of its softness after forging to shape, must be put through two processes known as "hardening" and "tempering." The first consists in heating the steel to a red heat (750 to 845 degrees C.) and then suddenly cooling it to the temperature of the atmosphere by immersion in a suitable bath. As previously stated, the heating of the steel above the point of recalescence causes the form of the carbon in it to be changed from "softening" to "hardening." The sudden cooling to the atmospheric temperature prevents the return of the carbon to its "softening" condition. Were an attempt made at this stage to use the tool without further treatment, it would be found to be excessively hard and brittle and totally unsuited for its work. It is, therefore, necessary to restore it in part to its original condition and this is done by tempering (drawing the temper), to accomplish which the steel is re-heated to between 200 and 300 degrees C. If heated to a still higher temperature, its condition would become more and more soft, until at about 315 degrees C. it would become entirely softened.

To assist in obtaining a uniform temperature during the hardening process, a bath of molten lead is sometimes employed, the temperature of the bath being controlled by means of a pyrometer. This method has the further advantage of preventing cracks through an uneven heating of the tool, as well as of excluding oxidizing gases which, in contact with the heated steel, would lead to the formation of scale and blister.

No small skill is required to harden and temper tools of this class successfully; for, while they have, as a whole, certain broad limiting temperatures within which the operations may be performed, each particular brand of steel has, in turn, much narrower limits which must not be exceeded if satisfactory results are to be obtained. there are further precautions to be observed, such as heating the tool uniformly and gradually; and subsequently, when tempering, cooling it in such manner as to produce extreme hardness on the nose yet, at the same time to give toughness to the body of the tool.

In 1868, Robert Mushet, then manager of the Titanic Steel & Iron Company (England), produced a tool steel containing both tungsten and maganese in comparatively large quantities. When this steel was raised to a temperature above 750 degrees C. and then cooled in the atmosphere, the presence of these elements retarded very appreciably, in point of time, its return to a softened condition; so much so that the steel reached a normal atmospheric temperature before the transformation from a hardened to a softened condition

had been effected. For this reason the steel received the name of "self-hardening" or "air-hardening," and tools from it were capable of being operated at higher speeds than carbon steel tools. This steel may, therefore, be looked upon as the forerunner of the high-speed steels of to-day.

The forging and the treatment (hardening and tempering) of high-speed steel tools, while similar to the corresponding operations with carbon steel tools, are, no doubt, less difficult on account of the impossibility of injuring them by heating to excessive temperatures. Many manufacturers recommend, in fact, the elimination of the process of drawing the temper in the general run of high-speed cutting tools. There is also a more noticeable trend every year to uniformity in the manufacturers' directions, which accompany each brand, setting forth the special rules to be followed with it. Mr. Taylor states that "little attention need be paid to these directions because all good high-speed tool steels should be treated in the same simple way." The word "simple" must, however, here be considered in the comparative degree; for, the making of good high-speed steel tools is not an especially easy task. As summarized by him with reference to lathe or planer tools, the process consists of two steps, the first a "high heat" treatment or "hardening," the second, a "low heat" treatment or tempering. In the high heat treatment, the tool is—

A— Heated slowly to 812 degrees C.
B— Heated rapidly from 812 degrees C. to just below the melting point.
C— Cooled rapidly to below 840 degrees C.
D— Cooled either rapidly or slowly from 840 degrees C. to the temperature of the air.

In the second or low heat treatment, the tool is—

A— Heated to 620 degrees C. for about five minutes.
B— Cooled either rapidly or slowly to the temperature of the air.

Heating a chromium-tungsten tool to about its melting point, imparts to it the quality of "red hardness" quite distinct from hardness in the sense that it is usually understood, and described by its discoverers not as a degree of hardness unusual in tools but as a property by which a tool is enabled to retain whatever degree of hardness it originally possessed, even after working it in service up to a red heat. It is of the utmost importance never to permit a tool which is undergoing the high heat treatment to become re-heated during the

first part of the cooling process; that is, between the limits of its melting and its recalescent point, for it has been shown that tools chemically the same but subjected to such re-heating give totally unlike results in performance.

To assist in obtaining uniformity of temperatures the molten lead bath mentioned as being used in the hardening of carbon steel tools is quite frequently employed in the cooling of high-speed steel tools from the high temperature to below the point of recalescence. The same bath is also used in the tempering or low heat treatment of the tools.

With the idea of still further extending the use of a molten bath so as to make it available for the hardening or high heat treatment of high-speed tools, an electric furnace has been recently constructed in which molten copper forms the bath. Experiments thus far made indicate that this may prove a simple and reliable method for commercial work, though time will be required to demonstrate its ultimate success. Steel when heated to between 700 and 800 degrees C. becomes non-magnetic and continues so as long as it is thus held, returning to its former condition upon cooling. It will be observed that these limits of temperature correspond to those for the "critical points" or "points of recalescence" of steel; that is, they are the same as the temperatures to which it is necessary to raise steel in order to soften or temper it. Based upon this principle, two forms of muffle furnace have been developed for tempering small tools. In one of these a horse-shoe magnet wound with suitable coils through which current flows, is embedded in the top of the furnace with its poles projecting vertically downward. The tool is placed within the furnace and against the poles of the magnet where it is firmly held. When the critical temperature is reached the tool loses its magnetic qualities and falls to the floor of the furnace. It is then removed from the furnace and chilled in the customary manner. When this process was first used, it was found that the tool, especially when of small cross-section, was not thoroughly homogenous, due to its contact with the poles of the magnet, which prevented the parts thus in contact from reaching the same temperature as the more exposed parts. By introducing between the tool and the poles of the magnet a metallic strip of proper dimensions, this difficulty was readily overcome.

In the other form of furnace three flat coils are used, two being placed on one side, one on the other and equally spaced on an axis extending through the body of the furnace at right angles to its

length. The two outer or primary coils (one on either side of the furnace) are connected in series with a source of current, the third or secondary coil being connected to a telephone receiver. The tool is placed in the furnace and a very pronounced sound is at once heard in the receiver, continuing until the tool reaches its critical temperature. The volume of sound then becomes materially reduced and the tool is at once removed from the furnace and the tempering completed as usual.*

Mr. J. M. Gledhill, of Sir W. G. Armstrong, Whitworth & Co., describes † a very ingenious method of using electricity in the hardening and tempering of tools. In the hardening process an iron tank is provided containing a strong solution of potassium carbonate. The tool is connected to the positive lead of a direct-current dynamo, the negative lead being connected to the tank. Upon lowering the point of the tool into the solution, thus closing the circuit, current flows and gradually raises the temperature of the tool to the required degree. The circuit is then opened and the tool continuing to remain in the solution, is rapidly cooled and at the same time hardened.

### THE LIFE OF THE TOOL

By the life of the tool is meant the length of time it can be kept working at maximum efficiency before re-grinding becomes necessary. This is dependent upon—

A— The quality of the material to be cut.
B— The composition of the tool.
C— The hardening and tempering of the tool.
D— The shape of the tool.
E— The speed and feed.
F— The dimensions of the cut.
G— The cooling fluid.

Excepting the first two items and to a lesser extent the third, these several requirements can be met with reasonable exactness. It is almost impossible to determine in advance with any degree of refinement the quality of the material to be worked; for example, it may be gritty on the outside while in reality soft and easy to cut; or it may be hard in portions, depending upon the mixing of the ingredients,

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*In the *Electric Review* (August 10th, 1906) a furnace of this type is described by one of the inventors, Mr. W. Taylor, under the title, "A Magnetic Indicator of Temperature for Hardening Steel."

†In a paper on "The Development and Use of High-Speed Tool Steels," read before the Iron and Steel Institute.

their qualities and the temperatures of melting, pouring and annealing (where this enters in), any of these conditions making all calculations as to feeds, speeds and wear on the tool of little account. However, a knowledge of the rules and customs of foundry work, including an analysis of the material, will enable certain conclusions to be drawn and used as a basis in ordinary commercial work. The quality of the tool steel is likewise affected by some of these same conditions that affect the quality of the material to be worked.

Manufacturers of high-speed tool steels advocate it for finishing, particularly in connection with lathe work and automatic machinery. It is claimed that the article is produced not only more rapidly but more accurately, owing to the greater resistance of the tool to wear. High-speed tools have undoubtedly proved of the greatest advantage for roughing purposes; for finishing, they have still to be shown superior, everything considered, to the carbon steel tools.

### SHAPE OF THE TOOL

In the design of a roughing tool for all-round work, so many opposing features require consideration that it may be said the resulting tool is a compromise affair, embodying no one idea to the exclusion of any other. This feature will be quite evident when some of the more important of these features are enumerated:

A tool with a perfectly straight cutting edge has a tendency to chatter; a round nose tool reduces this tendency and thereby produces a more evenly finished piece of work. A tool with a large radius to the nose may usually be run at a higher speed than one with a smaller radius, but the chip is thinner. Clearance is necessary between the tool and its work below the cutting edge; the greater this clearance, the more readily the tool cuts and the less the liability of the under portion riding against the work; on the other hand, the greater the clearance, the weaker the nose of the tool becomes with the consequent increasing danger of its crumbling away. A tool should always have back slope as well as side slope; that is, a downward slope on the top away from the cutting edge as well as to one side. Like clearance, back slope and side slope both weaken the nose of the tool; but, while back slope piles the chip against the tool post, side slope turns it to one side; the real purpose, however, of both side and back slope is to give the proper clearance to the cutting edge of the tool and thus to reduce the tendency of its being pushed away from the work.

As to the body of the tool, European preference leans to the

square cross-section, while American custom is strongly for the rectangular section with greater depth than width. In favor of the square cross-section may be mentioned the increased security from upsetting, for the resultant of all the forces acting upon the tool lies well within the base; the rectangular section with greater depth than width, posseses superiority in the matter of strength and, by bending the nose considerably over to one side, the line of the resultant force may be made to approximate that of the square cross-section. These points are shown graphically in Fig. 1.

Having now outlined some of the points which may enter into the design of a roughing tool, the query naturally presents itself as to what is the correct shape. Experience has demonstrated that for all-around work, either on hard material or on soft, in the smallest lathe or on the largest boring mill or planer, the round nose tool is best.

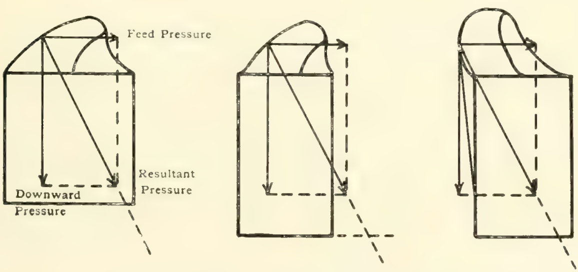


FIG. 1—SHOWING EFFECT OF SHAPE OF TOOL ON ITS STABILITY

Regardless of size or class of work, the contour of the nose is about the same, but the angles of the edges as well as the bluntness of the nose vary.

Where any considerable amount of tool steel is used, it is obvious that to obtain the best and most uniform results, standard shapes and sizes should be adopted and all tools made in accordance with them. With this end in view many large shops have established central tool departments fully equipped with labor-saving devices, in which all tools are prepared for use. They are then distributed among sub-tool rooms as occasion demands, where they can readily be obtained or exchanged by workmen without loss of time. In many instances the standard shapes are slightly modified by the workmen by a few minutes further grinding to suit conditions, real

or imaginary, peculiar to each job. It is interesting to note that Mr. Taylor recommends a clearance of six degrees and a back slope of eight degrees for all sizes of tools. The side slope, however, changes, being fourteen degrees in the case of tools for cutting hard steel and cast iron and twenty-two degrees for cutting medium and soft steel. The radius of the nose is derived from the formula,—

$R=1/2A-5/32''$ for blunt tools

$R=1/2A-3/16''$ for sharp tools

where $R$=radius of point and $A$=width of tool.

As to whether or not these figures are correct, there will be differences of opinion, as many, perhaps, as there are tool rooms in the land, each of which almost invariably professes to have one or more shop secrets of its own on this subject. The advantage of the argument must, however, rest with those who have used strictly scientific methods in their investigations.

### APPLICATIONS OF HIGH-SPEED TOOLS

High-speed steel tools, as their name implies, are capable of being operated at considerably higher speeds and feeds than cutting tools made from the ordinary carbon steels. Their advent into commercial work compelled machine tool builders to re-design their products, so as to make them suitable for these higher speeds and feeds with their attendant increased strains, etc. Manufacturers, even though they recognized the merits of high-speed cutting tools, could not, for obvious reasons, discard all of their machine tools which were not strictly adapted to the new order of things. Before them, therefore, was placed the perplexing problem as to what extent their machine tools could be used advantageously with these high-speed cutting tools or to what extent their machine tools should be altered or replaced.

From this it will be seen that in commercial manufacturing as it exists to-day, there are of necessity two standards of maximum speeds and feeds, depending upon whether one refers to the machine tool or to the cutting tool. The situation between these may be likened to that between armor plate and armor piercing projectiles, each of which holds for a time the advantage over the other until some new discovery changes prevailing conditions.

Considering a particular machine tool, the maximum speed and feed at which it should be worked in connection with a certain class of material can be found only by actual trial. When making such an investigation, all of the factors entering into its operation should

be taken into account at the very outset and but one of them changed at a time, the others remaining constant. It is of the utmost importance, too, that these factors be prime and not composite. A few years ago elaborate tests on high-speed steels were made at the Manchester (England) School of Technology. Mr. Taylor, in commenting on these tests, points out that the value of some of the data then obtained is very much detracted from, because the area of the cut was taken as a single factor, the assumption being made that the effect of depth times width was always the same, whereas the width of feed has a greater influence than the depth upon the cutting speed.

The difficulty of establishing a proper basis of comparison for high-speed steels will be fully appreciated by anyone who has endeavored to make practical tests with a view to the adoption of one or more makes for shop use. Mr. Taylor states that having tried many methods of comparison, he recommends a standard test of twenty minutes during which the tool should be operated at such speed as to be completely ruined at the end of the test. These conditions, however, do not necessarily apply to the subsequent use of a tool in the shop, though he further continues "the man who boasts of having run a tool without regrinding, say, for a longer period than one and one-half hours on ordinary shop work, is merely boasting of how little he knows about the art of cutting metals cheaply." Judging from the testimonials, etc., in the pamphlets issued by some makers of high-speed tool steels, decided exception will no doubt be taken to this statement by them and by certain of their customers as well. In making such a sweeping remark, Mr. Taylor undoubtedly had the cutting tool, solely, in mind, and intended to convey the idea that it was not being worked at its "most economical speed;" in other words, was not being pushed for all there was in it.

While the preceding may all be true, it may, nevertheless, be strict economy, from the manufacturing standpoint, to work the cutting tool at less than its "most economical speed" if thereby the machine tool be made to operate at its most economical speed. In shop practice, a tool should ordinarily last one whole cut, as its breaking down before the completion of a cut means a considerable loss in time and expense both to the employer and to the workman.

In shops where an incentive exists for rapid production, it will be observed, as a general rule, that the unskilled workman, in his endeavor to finish a job in minimum time, will work his tools harder than the experienced mechanic who has found, on the contrary, that the highest average rate of working his tools pays better. High-

speed steel tools are expensive in first cost and in subsequent upkeep, and, when the active stock amounts to thousands of pounds as it does in many shops, it makes a tremendous difference in tool and in tool-room expenses whether a workman returns two or six tools daily for repairs.

As showing the speeds and feeds practically attainable on the basis of the cutting tool being worked for one hour and thirty minutes without regrinding, the two following tables, reproducing in part data compiled by Mr. Taylor, will prove of interest. The tool used was a one-inch round nose tool of approved design and composition.

TABLE I

SHOWING THE SPEEDS AND FEEDS PRACTICALLY ATTAINABLE WITH HIGH-SPEED TOOLS OF APPROVED DESIGN WORKED FOR ONE AND ONE-HALF HOURS WITHOUT REGRINDING [TAYLOR]

| Depth of cut in inches | Feed in inches | Cutting Speed in Feet per Minute | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cast Iron | | | Steel | | |
| | | Soft | Medium | Hard | Soft | Medium | Hard |
| $\frac{3}{32}$ | $\frac{1}{64}$ | 226 | 113 | 66.0 | 490 | 245 | 111 |
| " | $\frac{1}{32}$ | 117 | 88.4 | 51.6 | 339 | 169 | 77 |
| " | $\frac{1}{16}$ | 130 | 64.8 | 37.8 | 235 | 117 | 53.4 |
| " | $\frac{3}{32}$ | 107 | 53.5 | 31.2 | 189 | 94.5 | 43 |
| " | $\frac{1}{8}$ | 92.8 | 46.4 | 27.1 | ...... | ...... | ...... |
| " | $\frac{3}{16}$ | 75.7 | 37.8 | 22.1 | ...... | ...... | ...... |
| $\frac{1}{2}$ | $\frac{1}{64}$ | 132 | 66.2 | 38.6 | 232 | 116 | 52.7 |
| " | $\frac{1}{32}$ | 104 | 51.6 | 30.2 | 161 | 80.5 | 36.6 |
| " | $\frac{1}{16}$ | 75.8 | 37.9 | 22.1 | 111 | 55.7 | 25.3 |
| " | $\frac{3}{32}$ | 62.6 | 31.3 | 18.3 | ...... | ...... | ...... |
| " | $\frac{1}{8}$ | 54.2 | 27.1 | 15.8 | ...... | ...... | ...... |
| " | $\frac{3}{16}$ | 34.2 | 22.1 | 12.9 | ...... | ...... | ...... |

Both iron and steel contain carbon in its two states, combined and graphitic, though the total amount of carbon is usually much greater in iron than in steel. It is a well known fact that as the percentage of combined carbon increases the metal becomes harder, and while this may therefore account in part for the difference in cutting

speeds between soft, medium and hard iron or between soft, medium and hard steel, it does not explain why the cutting speeds for steel should be higher than the cutting speeds for the corresponding grades of cast iron. Mr. Taylor offers as a possible solution, though with some hesitation, a very ingenious theory: Cast iron when compared with steel is practically without stretch. This absence of stretch or inability of the metal to flow causes the entire pressure of the chip to concentrate upon the lip of the tool close to the cutting edge, thus tending to heat it excessively. In steel the stretch is very considerable thereby enabling the metal to flow or spread itself out in a thicker chip over the top of the tool, the thickness of the chip

TABLE II

SHOWING HOW PRESSURE OF CHIP ON TOOL AND ALLOWABLE CUTTING SPEED ARE AFFECTED BY THE KIND AND QUALITY OF THE METAL BEING WORKED (TAYLOR). DEPTH OF CUT = $\frac{3}{16}$ INCH, FEED $\frac{1}{16}$ INCH

| | Kind of metal | Total per-cent of carbon | Percent of combined carbon | Pressure of chip on tool in tons per square inch sectional area of cut | Percent of stretch | Cutting speed in feet per minute |
|---|---|---|---|---|---|---|
| CAST IRON | Soft | 3.062 | 0.459 | 53 | ...... | 100 |
| | Medium | 3.305 | 0.585 | 94 | ...... | 49 |
| | Hard | 3.025 | 1.150 | 92 | ...... | 32 |
| STEEL FORGING | Soft | 0.20 | ....... | 128 | 29 | 111 |
| | Medium | 0.28 | ....... | 121 | 26 | 80 |
| | Hard | 0.51 | ....... | 168 | 14 | 41 |

depending upon the relative softness of the metal. As a result the pressure per unit area upon the lip surface of the cutting tool in contact with the metal, as well as the consequent heating effect, is probably as great with cast iron as with steel; again, graphitic carbon is present in cast iron to a greater or lesser degree, while in steel it is almost nil. This material acts as an abrasive, thus increasing still more the wear of the tool. These various points are well brought out in the succeeding table, as is the further point that no direct proportion exists between the cutting speeds and the pressures on the tool.

No one thing has done more to give an impetus to the use of high-speed steel cutting tools than the variable speed motor. In the

average machine tool equipped with belt drive, the changes of speed are usually quite limited and frequently either the nature of the work or the trouble involved in changing from one speed to another prevents the workmen from taking advantage of them. Through the medium of the variable speed motor, maximum cutting speeds can be obtained regardless of the diameter of the work or of the number of times the diameter changes in the course of a single cut. As illustrating this feature one or two instances will suffice, though numerous others can readily be cited.

In certain large turbo-generators designed somewhat as shown in Fig. 2, it is necessary to face or turn the ends of the stationary frame. In this work, which is performed on a large boring mill, the workman operates his machine at normal speed only during that portion of each revolution in which the tool is engaged in cutting the projections at *a* and *b;* through the remainder of the revolution, he is enabled by a simple movement of the controller handle to operate at a much greater speed, thus materially decreasing the time taken for the cut.

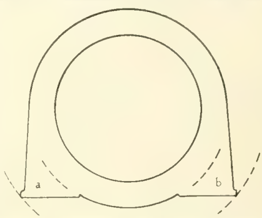


FIG. B—FACING OFF TURBO-GENERATOR ENDS—SHOWING SAVING IN TIME THROUGH THE USE OF VARIABLE SPEED MOTOR—SOLID CONTINUOUS CUT UP TO INNER DOTTED CIRCLE, INTERRUPTED CUT ON *A* AND *B*

Large shafts also, especially when requiring shoulders or grooves, are turned in far less time when the lathes are driven by variable speed motors than when they are equipped with any other form of speed changing mechanism, belted, coned or geared.

Several advantages are derived from the use of a copious stream of soda water or oil properly directed upon the nose of the tool; the cutting speed is increased from 35 to 40 percent, the power required for driving is reduced from 18 to 25 percent and the finish of the work is of a higher grade, though this last feature is not ordinarily of great importance in roughing work.

# RAILWAY SIGNALING—IV

## THE ELECTRIC TRAIN STAFF SYSTEM

T. H. PATENALL

### DEVELOPMENT

THE electric train staff system of to-day is a gradual development from a simple principle for the operation of railroads which was recognized in England as early as 1840; namely, that to safely pass over a given section of single track, every train should have in its possession a tangible right to do so in the form of some specific article of which there is only one obtainable. The first train staff was a metal bar about two feet long, which had cast or engraved on it the name of the two stations between which it alone gave authority for any train to proceed. Unless trains moved alternately in opposite directions the staff had to be returned over the section by a special engine or in some cases by road.

To partially overcome this difficulty the staff and ticket system was devised, in which device the original staff became a key that would unlock a box at either end of the section and permit tickets to be taken therefrom. If it was desired to forward, say three trains from one station to another before one should proceed in the opposite direction, the ticket box was unlocked by the staff and a ticket given to the first and second trains, the third train receiving the staff.

Since an engineer or guard of any train when receiving a ticket was required to see the staff as well, this system, while making head-on collisions impossible, did not permit trains to enter a section from the end at which the staff did not happen to be. To accomplish this result, Mr. Edward Tyer, in 1878, introduced his electric tablet apparatus, which consisted of two instruments, one at either end of a section, each instrument containing a certain number of tablets any one of which constituted the right of a train to pass over that section. The two instruments were electrically connected and synchronized so that the removal of a tablet from either instrument absolutely prevented any other being taken out.

In 1889 Mr. Webb, the chief mechanical engineer, and Mr. Thompson, the signal superintendent of the London & Northwestern Railway, invented the Webb & Thompson electric train staff, in which staffs were substituted for the tablets in the Tyer system and a permissive feature added whereby several trains could follow each

other into a block section if desired, in a manner similar to that employed in the non-electric staff and ticket system.

The first installation of the Webb & Thompson system was made with eminently satisfactory results in May, 1894, on the Chicago, Milwaukee and St. Paul Railway between Savanna, Ill., and Sabula, Iowa, and is described herewith:

APPLICATION OF TRAIN STAFF SYSTEM *

"The lines of the Southern district of the Chicago, Milwaukee & St. Paul Railway cross the Mississippi river between Savanna, Illinois, and Sabula, Iowa. The distance between these two stations is three miles, and there is one grade crossing, one draw bridge, and one local station in the block. Over this track, which is single, the traffic of about three thousand miles of the St. Paul company's lines passes. These lines extend directly to Kansas City, Omaha, Sioux City and Chamberlain on the west, and to Chicago, Milwaukee and Racine on the east. During the larger part of the year the traffic is heavy (the bridge block being the neck of the bottle, so to speak) and rarely falls below fifty trains per day at any time.

The division yard is located at Savanna, on the east side of the Mississippi river, making it necessary for the trains of both divisions west of the river to use the bridge block, and, moving the traffic from so large a territory, it is to be expected that they will be irregular in number, and that they will bunch during certain hours. The use of a time table showing the trains over the river block was abandoned, because it was found impossible to arrange it so that it was a reasonably correct exhibit of the traffic. Nor was it possible to move the trains through the dispatchers of either division, as the work on their respective divisions would not permit the close attention to the bridge block which the nature of the service demanded. For a time in the early history of the bridge this was done, but the work was finally put in the hands of the operators at each end of the block. It was found to be necessary to use some other than the ordinary dispatching systems. That was found to be too slow and cumbersome to meet the requirements of the quick work necessary under the conditions constantly arising incident to unexpected delays, and to increase or decrease of traffic. To meet the conditions described a train order by card system was adopted, which was in successful use for

*From a paper read before the Western Railway Club by Mr. C. A. Goodwin, at that time superintendent of the Chicago, Milwaukee & St. Paul Railway.

many years. It was virtually a staff system—the card representing the staff—but it lacked one element: it was impossible to interlock the cards. As traffic increased, and increased acceleration of trains became necessary, it was apparent that the company would be compelled to either double-track the bridge block or find some unobjectionable way of handling the trains. Owing to the character of the country the construction of a second track would have been very expensive, and the selection of a satisfactory system for handling the traffic became the subject of much thought and investigation. After a thorough examination and inquiry the Webb-Thompson electric staff system, largely in use on the London & North-Western Railway and in Australia, was adopted and placed in service in May, 1894. This was the first installation of the staff system in the United States, and probably in either of the Americas.

"From the preceding brief description it is clear that with this system the bridge dispatcher has no responsibility except to give the proper trains the preference. He may delay traffic, but he cannot create a condition of danger. It is not necessary for him to provide for a proposed or supposed movement of trains by sending numerous orders, only to find it necessary to cancel them because the train cannot move as expected. He is in touch with the yardmaster at Savanna and with the dispatcher at both divisions, and through these sources is fully informed in regard to the probable movement of trains in both directions. He may have expected to hold a freight train for a passenger train, which is reported on time at some distant station, only to find that the passenger train has lost time and that he can just squeeze the freight train into the terminus. There is no necessity for sending hurried orders with attendant possibility of errors. He simply signals for a staff, and in five seconds or less the engineer has his authority to go forward. Or supposing the situation reversed. A passenger reported late has made up so much time that another train which is approaching, and for which a staff has been withdrawn, cannot go forward. Transportation men know the delay which results when it is necessary to change or make void telegraphic orders. No such delays occur with the staff system. It is only necessary to leave the signal at danger, replace his staff in the instrument (enabling one to be withdrawn at the other end of the block,) and the passenger train goes forward with no loss of time. In case of there being so great a delay to a train, to which a staff has been delivered, that it is desired to recall its permission to move, the staff is brought back to the office and replaced in the instrument,

thereby cancelling its authority to proceed and in a manner which cannot be misunderstood.

"When a work train is to occupy the block the delivery of a staff means that it is to be protected in both directions, and that no flagman need be sent out, delaying fifty or a hundred men while he comes in.

"These few examples of the many complications that must necessarily arise in the handling of traffic on a single track are cited to illustrate the facility with which the staff system does its train dispatching; its possibilities in connection with the movement of trains on single track, and its especial adaptability to short stretches of track used by the trains of several divisions or different railways, as compared with the telegraphic movement; the advantage both as regards safety and facility of handling being distinctly with the staff system.

"It is not the intention to decry our system of train dispatching. There can be no question but what it is a most economical and satisfactory method of handling traffic under ordinary conditions with not too heavy a train movement; but we are obliged to admit that the system is open to objections which particularly relate to safety as well as facility. The staff system is capable of extended application. It is at once a block signal, a train dispatcher and a time table. It is to the movement of trains between stations what the interlocking of switches and signals is at stations and grade crossings."

The main objection to the extended adoption of the Webb & Thompson apparatus was the size of the staff, which made it difficult to catch at high speed. To overcome this objection, a new design was introduced in 1900 as the high speed train staff system was based on the same general principles and method of operation as the Webb & Thompson, but possessed the essential advantage of employing staffs only six inches in length, weighing six and one-half ounces; as against staffs twenty-two inches long, weighing four pounds, of the Webb & Thompson system, thus greatly simplifying the problem of taking the staff at high speeds.

On the Atchison, Topeka & Santa Fe Railway, among other places, it was applied to a section extending from Trinidad, Colorado, to Raton, New Mexico, a distance of 25 miles, which was divided into seven block sections. This portion of the Atchison comprises mountain grades averaging three and one-half percent for a greater part of the distance, over which a traffic of approximately 60 trains a day is operated. On account of the number of trains, and also from the fact that each train required two and sometimes

three engines on the up-grade, an average of one hundred and fifty train orders was issued in each twenty-four hours, most of which were sent to not less than two stations, so that the total delay to trains awaiting these orders can easily be imagined. With the introduction of the staff system as many, or more, trains have since been handled over this section with no collision and a minimum of delays. At the intermediate stations on this section, staff cranes are provided from which the enginemen can take the staffs at a speed up to 25 miles an hour without the use of any special attachments on the engine.

The latest type of staff instrument, known as the electric high-speed train staff, Model No. 2, has been developed during the past four years, and employs practically the same size and weight of staff as the Model No. 1 machine, over which it possesses the following advantages: By having separate drums for putting in and taking out the staffs, equal wear on all staffs is secured; whereas, in the earlier instrument some of the staffs would be practically worn out from constant use, while others were hardly ever used at all. The second advantage lies in the special type of indicator employed in this machine, which plainly shows the operator by the display of a white or red disc whether or not his instrument is in condition for him to remove a staff, and thus leaves him no excuse for unduly forcing the mechanism. Numerous other improvements exist in this type of machine, but they consist principally in minor details of construction.

An installation of this type has been in operation over fifteen months on a section of the Southern Pacific Railway between Truckee, California, and Colfax, California, a distance of 98 miles, divided into 37 blocks. This portion of the Southern Pacific is in the Sierra Nevada mountains and 14 of the staff stations are located in the snow sheds, of which there are nearly 40 miles.

### PRINCIPAL ADVANTAGES OF THE ELECTRIC TRAIN STAFF SYSTEM

While in the foregoing the general principles on which the electric train staff is operated have been described, yet particular attention is called to the following points:

First—The electric train staff system may be considered as a mechanical assistant, which issues metal train orders under the general direction of the train despatcher, giving trains the right to proceed over certain sections of track, and will only issue one such order at one time for any section, except in the case of following

trains where the permissive feature is used, thus obviating all danger of "lap orders."

Second—In place of eliminating the train despatcher, as has at times been erroneously supposed, the train staff, by removing all dangers of collision and doing away with all train orders, relieves his mind from the constant strain imposed upon it under the present system and thus gives him ample time to isssue orders to operators on his division for the proper movements of the trains under his control.

Third—It avoids all the delay now experienced in waiting for train orders. If conditions are right for a train to proceed the staff can be obtained immediately and when the permissive system is employed trains can follow each other as closely as the rules of the road permit.

Fourth—It alone of all block systems provides a tangible piece of evidence in the shape of the staff to the engineer or conductor of his right to the particular block section he may occupy.

Fifth—It can be surrounded with all such aditional safeguards as conditions and locations may warrant, including semaphore signals and continuous track circuit, electric locks, etc.

Sixth—It can be safely operated by any railroad employee of average intelligence. A knowledge of telegraphy is not necessary for its operation.

Seventh—At stations where telegraph operators are employed who have other duties, it is found that the operation of the staff takes up considerably less of their time than is now expended on telegraphic train orders.

Eighth—In most installations, the absolute staff system is employed which permits but one staff to be out of any pair of machines at one time and consequently allows but one train in a block.

In a number of cases, however, where the blocks are of necessity long and traffic is heavy through certain portions of the day, the permissive feature is introduced which, while it makes it impossible for two trains proceeding in opposite directions to be in any given block at one time, permits as high as twelve trains to follow each other in the same block at close intervals.

(*To be continued.*)

# A BRIEF HISTORY OF THE WESTINGHOUSE MACHINE COMPANY

EDWARD H. SNIFFIN
Vice President

A RECENT request from the editor of the JOURNAL to prepare for its readers a brief sketch of the Westinghouse Machine Company suggests that a historical narrative, whatever the subject, to be of interest or value, should treat of the conditions and circumstances under which the subject acquired its significance. The Machine Company's business, for instance, if at all properly described, embraces a recital of the engine business of this country for the past twenty-five years. It started at a time when the electric light was a curiosity, and it might be said that the electric lighting business presented the principal objective field for its product, as the introduction of high-speed electric generators of rather small capacity created an obvious demand for engines of high rotative speed for direct belt drive, in place of slow-speed engines, with their various expensive and wasteful methods of speed reduction. It may be said, therefore, that the Machine Company's business has been fairly parallel in its growth with that of the electrical industry. A large preponderance of its product has been used in the electrical field, and its product has advanced in size and character in contemporaneous step with the growth and evolution of electrical generating apparatus.

The brief space allowed for this article, however, requires too close adherence to my subject to permit of what might not be a wholly uninteresting discussion of various interesting phases of steam engineering which have brought the Machine Company's product to the position it occupies to-day. Every one knows, of course, that the unparalleled growth of this country during the past twenty-five years is most fittingly symbolized in its mechanical achievements. In this development the Machine Company has played a fairly conspicuous part, and I will briefly narrate the progressive stages from its start, in January, 1881, to the present day.

The incorporation of the company was "for the purpose of the manufacture of machinery of all kinds, whether patented or not, the building of steam launches and boats and their equipment, and

dealing generally in machinery, patented specialties and manufactures by secret processes." It is amusing, in the retrospect, to note that its business, beside the building of the Westinghouse engine, was expected to comprise the manufacture of a certain style of feed-water heater, a device called the Alden Crusher, and a composition metal known as Damascus Bronze. Evidently, this mixed association of product did not possess commercially enduring qualities, for shortly thereafter the company's business became wholly confined to the Westinghouse engine.

### STEAM ENGINES

At this period, in 1881, the Air Brake Company was the only other Westinghouse concern in existence, if we except the old agricultural machinery concern at Schenectady, N. Y., bearing that name. The Machine Company began business in a works at Pittsburg formerly occupied by the Air Brake Company, which had recently moved to Allegheny into more commodious quarters. It began building the Westinghouse Standard engine, at first of the throttling type, but shortly afterward changed to the automatically governed form. A cheaper style, known as the Junior Automatic engine, appeared in 1887, it being a type quite comparable with the Standard engine in economy, though of a less expensive design, with plain exterior finish. The Compound high-speed steam engine appeared in 1888, and many will remember that it was a considerable innovation. At that time, now nearly twenty years ago, engine builders were contending that the compounding principle was of no positive value in engines of less than 100 horse power, and they were prone to say that compounding did not pay at all unless condensers were used. The Westinghouse Compound sizes started at 35 indicated horse power, and it soon became evident that this type of engine, even without the use of vacuum, improved the best simple engine efficiency, size for size, about 25 percent. The standard performance of simple, high-speed engines was considered to be about 32 pounds of steam per indicated horse power, while the compound engine, running non-condensing, took about 24 pounds, and, with vacuum, something like 18 pounds. It was not until some years later that condensers came into general use.

The Machine Company's business, then, in prime movers was confined, for the first sixteen years of its history, up to the year 1897, to the building of the Standard, Junior and Compound, single-

valve, single-acting, high-speed steam engines. During that time, about 7 000 of these engines, aggregating a little over 400 000 horse power, were installed. Viewed from the standpoint of bigness which everything has acquired in the present day, this high-speed engine work does not seem very striking in magnitude, but it was a large business then. We must not forget that size standards were a great deal smaller in those days. A thousand light alternator was then a large machine. A 500 horse power engine stood out to the eye and mind quite as pretentiously as would a 5 000 horse power engine now. The electrical salesman, now equipped with price and data book comprising hundreds, and even thousands of pages, at that time found his company's entire list of product covered a page or two of his pocket memorandum book. And the Westinghouse single-acting steam engine, if it seems to-day overshadowed by prime movers of different type and larger size, was in this former era a very potential factor in power work, the Machine Company then possessing, as an engine building concern, hardly less prestige, relatively, than it enjoys to-day.

Nor was the reason for this at all obscure. Not alone did the engine as a type possesses the essential elements of engineering success, viewed from its design, its method of manufacture, its inherent workable qualities,—from whatever standpoint you will, but its exploitation was attended, I think, with a rather unusual comprehension of the problems—many of them new ones—arising from the use of power. The consulting engineer had scarcely arrived, and with the engine builder commonly confining his scope to the building and selling of the engine, with a perfunctory, or, at best, mediocre interest in the application, the customer, himself as yet unaccustomed to problems of the kind, was painfully conscious of the haphazard character of his engineering work. The Machine Company's work became established on the definite lines of two distinct divisions,—one the manufacturing of the engine itself, the other the marketing of the product through an organization which, in addition to its agency functions, applied the experience of a trained engineering force in fostering proper conditions of installation and discovering economical methods of application. The engine being built by the Westinghouse Machine Company, was marketed by Westinghouse, Church, Kerr & Co. This method, giving as it did a strong engineering integrity to the business in the Westinghouse engine, was no inconsiderable factor in the growth and prosperity of that business.

But it may be said that the engine was equal to the method. In fact, had it been otherwise, either the engine or the method, or perhaps both, had soon perished. But they grew and flourished together, the engine paving the way to the present magnitude of the Machine Company's work. The engineering motive which grew with it, expanded and embraced new fields until it became large enough and strong enough to form the independent foundation of an organization devoted solely to engineering work—to-day the largest and most comprehensive organization of its kind.

The history of the Westinghouse single-action steam engine is not without interest. If the success of an engine is measured by its performance, by its continued use, by the profitable business it has yielded, and the maintaining of its position among engineers and purchasers, then this engine should be called a success. Yet, being a radical type of machine, departing quite widely from conventional high-speed engine design, it has perhaps been more fully discussed and been the subject of more conflicting opinions than any other machine of any kind. One or two reasons for this are recognized. Being distinctive in type, with nothing else like it, and being formidable in trade, it has contended with many competitors, which latter, differing only in details of design, have in a sense assailed it in combination. Mr. Wallace Franklin used to say that you found the most clubs under the tree bearing the best fruit, a truth which I think herein finds some application. Competitive accusation, never dignified at best, has usually assailed its steam economy. Such statement, easily made, but not always easy to quickly refute, was bound in its reiteration to acquire some vitality, but it has always been easily and authoritatively answered by the evidence of many thousands of tests made by the builders and by customers themselves. Any customer is privileged to test his own engine before shipment, if he desire, and its efficiency will be maintained if he keep his engine in proper condition. The only debatable point I have heard advanced in criticism of the Westinghouse engine, on the score of its general utility and commercial status as a high-speed engine, was the statement that the term "automatic" fitted it too well; that in character it was an engine which invited neglect, and too frequently received it.

A good many Westinghouse engines have given trouble because they were thought to need little or no attention, which fact, however, if employed in derogation of the engine, would, it seems to me, serve more appropriately as a condonement of careless attendance,

a thing which in varying degree will result in trouble with any machinery. Would we not term as absurd the inverse proposition that a design which required scrupulously watchful care, and because of such watchfulness managed to operate pretty reliably, was for that reason a design of merit and desirability? The fact is that the Westinghouse engine is a machine requiring, in common with all other machinery, good care in its operation. It is a rugged, reliable form of engine which will stand a good deal of abuse, but should not on that account be neglected. If it be consistently maintained, it will give good service, showing a low repair cost, and a steam efficiency quite within the best accepted standards for engines of that class.

If I have appeared to drift from my main subject to dwell for a moment on one class of the company's product, it is because that product was for many years the company's sole prime mover output, the one particular thing with which its name was linked, a product, too, which, even at the present time, is a considerable factor in the engine trade, and concerning which these few remarks, borne of twenty years' observation of the subject, may not be inappropriate.

By the year 1895, the Machine Company's Twenty-fifth Street quarters in Pittsburg had become too small, and in that year the construction of the East Pittsburg works was begun. The plant was laid out on the lines of Mr. Westinghouse's idea of a one roof plan, rather than being divided into a number of buildings. A shop some 600 feet long and about 225 feet wide was built, about one-fourth of the space being devoted to foundry purposes. The new works had scarcely started before it became necessary to tear down both end walls and extend the building in both directions, to 1 300 feet in length. These facilities sufficed until 1902, when the company started the building of its Trafford City foundry, which, connected with the company's East Pittsburg works by an inter-works railroad, is one of the most modern and efficient foundry plants in the country.

The iron foundry building is 600 feet long, 180 feet wide, and is of a design strong enough to carry traveling electric cranes which can lift and transport weights of 100 tons in a single lift. There are sixteen electric cranes employed throughout the plant. The melting is done by three cupola furnaces and two so-called air furnaces, the latter having a capacity of 45 tons each. The foundry can melt 200 tons of iron per day, and, if required to do so, could produce a single casting weighing 200 tons. No such casting has

ever been called for as yet, but the foundry and its equipment were designed to be ahead of the times and not merely abreast of them. A good laboratory is maintained and every article entering into the product, such as coke, coal, pig iron, scrap, etc., etc., is carefully analyzed and the quality of the product is thus insured and is under good control. The patterns from which all castings are made are manufactured and stored in a separate building belonging to the Trafford plant, and all of the company's past and now obsolete patterns are kept in storage there. This pattern building is three stories high, 80 feet wide and 600 feet long.

GAS ENGINES

The Westinghouse vertical gas engine was put on the market in 1897, in both the two-cylinder and three-cylinder designs. Up to that time, gas engines had been more or less toy affairs. They were built in sizes up to about 50 horse power, equipped with "hit-or-miss" governors, of course regulated very poorly and were used in various classes of light service requiring little refinement of operation. The Westinghouse gas engine was brought out to compete with the steam engine, and was built in sizes up to 600 horse power. It was used in all classes of power service, mostly for driving generators, both by belt and by direct-connection, in electric lighting, general power and electrical railroad work. This gas engine, following the mechanical design of the Westinghouse single-acting steam engine, has been conspicuously successful. It has come to be looked upon as a general standard of gas engine design, and several other builders have followed it as a type.

After building some 1 200 of these vertical engines, the company's gas engine work has culminated in the horizontal gas engine for the large sizes, which engine is, in fact, the company's latest engineering success. Its first engine of this type, a 500 horse power unit, was started in service at the plant of the Warren & Jamestown Street Railway Company in October, 1905, followed about a month later by a second engine of the same size in the same plant. Since that time a good many others have been installed elsewhere, running on different kinds of fuel gas, the largest being two 3 000 horse power gas-driven blowing engines at the Edgar Thompson plant of the Carnegie Steel Company. The first of these engines went into service so unqualifiedly well that it promptly established the large gas engine, driven by blast furnace gas, as practically the standard type of blowing engine and engine for generator drive in the steel

mills of the country, in which service it will unquestionably supplant the steam engine about as rapidly as the gas engine can be manufactured. It merely records a fact to state that this change in practice has occurred and a good many million dollars have been obligated because of the performance of these two engines at the Edgar Thompson Works, which at the present time are the only four cycle engines operating with blast furnace gas in this country.

The combustion engine is undoubtedly destined to soon occupy an important position in the power field. In thermal efficiency, it greatly excels the best types of steam prime movers. The gas engine is at the present time undeniably adequate, from a mechanical standpoint, to meet the present day demands of power service. It is, of course, restricted in the size of unit, and the problems of cylinder design may for the present keep the unit capacity below 5 000 horse power.

The gas engine, however, is only a part of a system in which the generation of the gas is of equal or perhaps even greater importance because of the still existing absence of established lines of practice. Moderate sized producer gas engine plants are now in successful operation, and the efficiency of such plant is not only very high, but in the nature of things will always remain more nearly constant than has ever been possible with steam plants. The capital account of such plants, at least until the art becomes older and manufacturing cost becomes in consequence reduced, will probably restrict their comparative value over steam plants to the cases where fuel is fairly high or scarce, or where water supply is meager.

The Machine Company started to build Corliss and poppet valve steam engines in 1899, and as if to keep in step with the country's spurt of that time in big and unprecedented undertakings, it took an order for sixteen 5 000 horse power Corliss engines before it had built a Corliss engine of any size. This order was afterward reduced to eight engines, because of a change in the customer's affairs. The company specialized on the larger sized Corliss work, the largest part of its trade comprising vertical engines to drive generators of from 2 000 to 4 000 kilowatts. Little attention was paid to the trade in small and medium sized Corliss engines, and the Machine Company, while it built some 232 000 horse power of Corliss engines, really conducted the work in a discriminating way, never giving itself over generally to work of that class, but instead maintained a variety of product, any one class of which might give way to another kind without material change in facilities or meth-

ods. Thus, the later change in the type of its large steam prime mover product was accomplished with comparatively little manufacturing inconvenience.

It might be said that its Corliss engine work brought the Machine Company, previously known as builders of small engines, prominently to public notice as a concern equipped with adequate facilities to undertake first-class work of large magnitude. This reputation, acquired contemporaneously with the inauguration of the large waterside power plants ranging from 25 000 to 50 000 kilowatts in nominal capacity, in many of which plants the Machine Company's product was used, brought it into a leading position in the large power field, and rendered most logical the initial position which it occupied in the next progressive step in stationary engine practice.

STEAM TURBINES

This step was the steam turbine, the engine of to-day. The experimental shop work was begun on the Westinghouse-Parsons machine in 1896. The first ones sent out were the four 400 kilowatt units for the Westinghouse Air Brake Company's plant, at Wilmerding. These were installed between August, 1899, and April, 1901. The first machine installed for an outside customer was the 1 500 kilowatt unit sold to the Hartford Electric Light Company, which was erected in June, 1901. Since that time the company has sold over 500 000 kilowatts of steam turbines. The steam turbine has by this time been the subject of so much investigation and publicity, and so much experience, that one scarcely feels interested in the questions that formerly surrounded it. It has become a recognized type of prime mover which has practically supplanted the reciprocating engine in electrical service, except in direct-current plants. The reader may not fully realize why this remarkable change, occurring within less than six years, has taken place. One can hardly see why the steam turbine, even with its many points of evident superiority, should have effected this metamorphosed condition of power plant practice. Why has it not taken hold gradually, in the way of most improvements? Is it really so much more economical in steam consumption or more reliable in operation, or cheaper in first cost, or what is it? Perhaps the reason is not so obscure. So far as first cost is concerned, I might tell you of the light which has been thrown on this phase of the question since the month of October, 1902, when I read a paper on the steam turbine

at the Detroit Convention of the American Street Railway Association. The subject was new, excited much interest and a good deal of discussion. Among the speakers some were advocates of the turbine, some were skeptics. One or two were radically opposed to the customer trying any experiments, though how a builder can work out a new thing unless the customer helps him, and helps him because of the possible benefits to be derived, they did not explain. Then followed a resentful criticism by one member of the prices at which steam turbines were sold. I explained then that the turbine was inherently a less expensive machine to build than the reciprocating engine, that while the price of necessity was high while the art was new and development still going on, it was certain that the turbine would in due time effect a marked reduction in the cost of prime movers, and of power plants as a whole.

Time has gone on, and purchasers of power machinery have witnessed a reduction in the cost of prime movers far beyond their greatest expectation. I have seen the last speaker above referred to purchase a turbine and generator within the last year for 15 percent less money than he paid for his engine alone less than five years ago. It is a safe general statement that the whole generating unit—turbine and generator—costs less now than did the engine alone up to the year 1903. But that is only the beginning. What of the foundation, the building, the real estate—the plant as a whole? Compare a typical turbine station layout, with the station arrangement as a whole simplified in keeping with the turbine,—compare this with the expensive piston engine plants we formerly put up, and I believe a difference of 25 percent in total plant cost would not be an exaggerated estimate. So much for first cost.

One other important factor, and perhaps the most important, in this revolutionary change of which I speak. Do you realize that the steam turbine consumption of the country is at present about one million horse power per annum? When you think of the manufacturing facility which attends steam turbine production and then regard the comparatively restricted production of reciprocating engines, the evidence seems clear that the power demands of the country could not be supplied with piston engines, or if supplied by greatly increased facilities, such supply would, as compared with existing conditions, be at large economic waste. And so the steam turbine has become a big factor in the general industrial scheme.

STOKERS

Apart from its engine business, the Machine Company builds

and sells the Roney Mechanical Stoker, a device manufactured at its Attica, N. Y., works, situated on the Erie Railroad, some twenty-five or thirty miles southeast of Buffalo. This business has been carried on about eighteen years, during which time some five thousand of these stokers have been installed under more than one million horse power of steam boilers. A very able engineer and business man once related to me a rule he established in taking the management of a large business comprising, among other things, the manufacture of steam boilers and mechanical stokers. He told his men to get after boiler orders, but to be mighty careful where they sold stokers. He said he was not looking for trouble; and he had had some experience. There is no doubt that it is a peculiar and specialized business by itself.

The stoker seems like a rather crude device, made up of comparatively rough castings. On the other hand, to burn fuel with a mechanical device in a reliable and efficient manner, this, too, with the average boiler room attendance, is an undertaking which requires a high order of engineering supervision. Wholly apart from the design of the device itself, there are a number of factors that make either for success or failure—such questions as that of draft, the quality of fuel, character of setting, method of operation, etc., all requiring to be considered if difficulties would be avoided. I would say that a successful stoker business depends about as much upon the way the business is handled as upon the design of the device itself. The Machine Company has handled it as an engineering business. Commercial questions pure and simple have always been subordinated to engineering considerations. It is in the stoker business to make money, but it early discovered that the only way to make money was to run it under engineering domination. By following this method consistently, it has raised the stoker business to a high engineering level.

Mechanical stokers are now almost invariably installed in large steam power plants, effecting improved efficiency, greater steaming capacity and saving of labor. There is an increasing public demand for the abatement of smoke. The different cities are putting through new smoke ordinances, or more strictly enforcing old ones. The mechanical stoker, while not a cure for this trouble, is a means to that end, and there will probably be more of them used in the future merely to aid in securing smokeless combustion.

SUMMARY

In summarizing the Machine Company's work, I would say it

has manifested the pioneer spirit quite fully, and withal, its labor has been characterized by a strong leaning toward assurance in the correctness of what it did. It was very early in the high-speed engine field, inaugurating the principle of sub-divided power, saving a large part of the transmission losses by locating small engines around a plant at their various points of use; which idea, by the way, finally culminated in the extensive use of the electric motor. It was one of the first, if not the first, to direct connect engines to generators. It brought the medium sized gas engine to a condition where it would give stable and dependable power. It initiated the steam turbine business, and is now in the vanguard with large combustion engines. In the main, its policy, under a direction which has given to all the Westinghouse concerns such recognized enterprise in their respective fields, has been not to settle complacently into conventional grooves and simply do well what others were doing, but, responding to new economic demands, it has sought to develop new types of power machinery and has devoted the necessary effort and expense to making such developments successful.

A recital of the work of this concern or that of any other one Westinghouse concern can be, at best, but a partial story. Perhaps we may at some time have a proper historical treatment of these great interests, representing as they do the life work of their founder, in which the accomplishments of the respective companies will appear with proper significance by being shown in their true relation. Such narrative would, indeed, reveal a man's work. It would show the economic and social benefits which have accrued to mankind from the efforts of tens of thousands of men working in organization under a great, inspiring leadership. It would, indeed, be a story of world's work.

# PROBLEMS IN COMMUTATION*

MILES WALKER

THE problems which arise in connection with commutation are very numerous. They are partly mechanical, partly electrical, partly magnetic, and partly thermal. In the old days of metal brushes there was not much trouble in the mechanical support of the brush, except that the rapid wear necessitated good feeding devices. On the advent of the carbon brush the problem of supporting it and feeding it in a satisfactory way became a more difficult one.

## MECHANICAL PROBLEMS

The mechanical problems are these: The surfaces of the brushes and of the commutator are to be kept in very close contact, notwithstanding the revolution of the commutator at a high speed. Both surfaces are hard and unyielding, so that it is only by having the most perfect fit that very close contact can be obtained. If the commutator is perfectly cylindrical and runs perfectly true and the brush be properly supported the surface will wear until the fit is perfect, but it is difficult to obtain exactly these conditions. Commutators do not in practice always run true nor are they perfectly cylindrical.

To minimize the trouble with the commutator when it is not true it is desirable to have parallel motion of the brushes so that the angle which the wearing faces of the brushes make with the commutator shall not alter. Any slight swivelling of the brush, such as takes place with pivoted holders, will always cause sparking if the commutator be untrue. Not all parallel motion brush holders, however, are satisfactory.

Probably the simplest and best is the sliding shunt type, in which the carbon is held in a rectangular box. In this it slides and is pressed down with a spring. The main objection to this type is the difficulty in securing an easy fit with a cheap method of manufacture, and at the same time ensuring that the carbon will not be too loose. Even after the carbon has an easy sliding fit in the holder it will sometimes clog with dirt, and require a greater pressure to make it feed. In the case of motors, in which the direction of

*Based on a lecture delivered by the author before the Engineers' Club of Manchester, England.

rotation is reversible, it is necessary to have the brushes fit very nicely in the holders, so that they will not wear one facet for the forward motion and another facet for the backward motion.

### CHATTERING

Many of the holders which have been designed to give parallel motion appear, at first sight, to be good, and do in fact operate fairly well. A common difficulty is that they are not free from chattering. Almost every electrical engineer at some time in his career has thought that he could devise a brush holder which would be superior to all others. If one has this ambition it would be advisable for him before beginning to make a thorough study of the theory and practice of chattering. Probably no one has yet completely mastered the subject, but there are one or two points which are sufficiently well established to be set down as first principles. Chattering is more likely to occur when the vibration of the brush can take place without friction than where any motion of the brush in a radical direction is accompanied by considerable friction. For this reason the frictionless parallel motion brush is more likely to cause chattering than one of the sliding type.

If a brush can be forced from its correct position in a direction tangential to the commutator, it is more likely to chatter than if it is rigidly prevented from moving. The main difficulty in most parallel motion brush holders is that they do not give sufficient rigidity in a tangential direction. Even with the sliding type of brush holder it is necessary to have very great rigidity in the arms of the brush holders to avoid chattering.

The importance of eliminating chattering is evident when tests on the friction losses in brushes are made. Separate tests of the coefficient of friction between the polished brush and polished commutator give a figure of the order of 0.1; that is to say, if there is a pressure of one pound pressing a brush on the commutator, it ought only to take 0.1 of a pound to turn the commutator. From actual tests on high speed commutators on which chattering is occurring, it is found that the losses may amount to two or three times the true necessary frictional loss.

### COMMUTATION ILLUSTRATED BY A MODEL

The process of commutation in a generator is illustrated in Fig. 1, which represents a ring winding with taps taken off to a commutator on which the brushes rest. As the commutator revolves, the

red and green colors* indicate the direction of the current in the armature coils. If the current in the coil between the bars *1* and *2* is considered, then so long as the coil is under the north pole the direction of the current is upwards on the left hand to the positive brush and is indicated by the red color. As the coil passes under the brush it changes its direction through the coil. All coils under the south pole have a current which is traveling upwards from the right to the positive brush. This is indicated by the green color. While the coil passes the brush there is a quick reversal of the current in it. The self-induction of the coil opposes this reversal, so

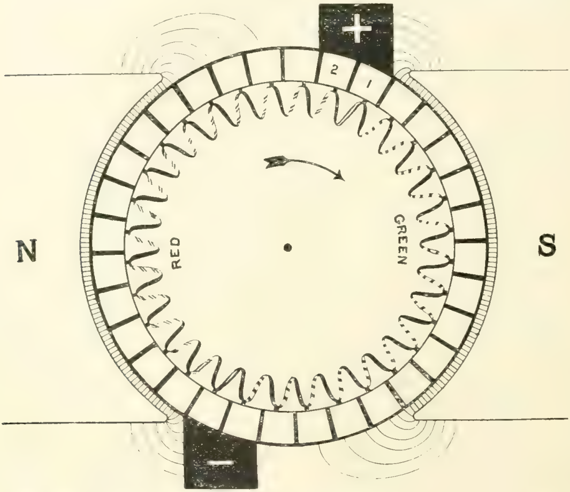


FIG. I—SHOWING ARRANGEMENT OF MODEL USED TO ILLUSTRATE THE PROCESS OF COMMUTATION

that as the bar *1* leaves the toe of the brush, the green current, rather than go suddenly through coil *1-2*, tends to jump through the air and make a spark. The best way to overcome this difficulty is to arrange matters so that there is an electro-motive force in the

*The red and green colors are indicated by the direction of slope of the lines drawn on the armature winding. The model of which Fig. 1 is a photograph is arranged with the armature mounted on an axis at the center so that it can be rotated. When rotated the effect is of current flowing towards the + brush (by a strobic effect). A light is placed behind the model and is so arranged that when the brushes are shifted out of their proper position, a bright spot is seen at the toe of the brush. The model, if properly made, gives a very effective illustration of commutation.

coil *1-2* while it is short-circuited by the brush. If this electro-motive force is in a direction which tends to oppose the red current and create a green current, and is of such an intensity that during the interval of short-circuit it can create a green current whose value is equal to the green current in the rest of the armature, then as the bar *1* passes away from the toe of the brush there will be no tendency for the current to jump through the air. This commutating electro-motive force in ordinary machines is obtained by rocking the brush forward so that the commutation takes place in those conductors which are moving in the weak field fringing from the pole. If the brush is rocked further forward to a point where the fringing field is stronger, the commutating electro-motive force is stronger, so that for any given load a point can generally be found at which the commutating electro-motive force is just sufficient to reverse the current during the short-circuit period. When metal brushes with low contact resistance were employed it was necessary to shift the brushes between no load and full load. If the brushes were left rocked forward at no load the electro-motive force produced by the fringing field caused currents to flow in the short-circuited coil which had to be broken as the bars left the brush; this caused sparking and burning. If, on the contrary, the brushes were not rocked forward far enough, the commutating electro-motive force on load was not sufficient, and sparking occurred. By employing a carbon brush and by designing a machine with sufficiently good commutating qualities, it is possible to run from no load to full load without sparking and without any shifting of the brushes. This is mainly due to the high contact resistance between the carbon and metal. Another way of looking at the matter is to consider that there is a back electro-motive force when the current is passed from carbon to copper or from copper to carbon and this back electro-motive force can operate partly as a commutating electro-motive force. In fact, so effectual is the contact resistance between carbon and metal that it is possible to commutate fairly well with the brushes on the true neutral point, or even on the wrong side of the neutral point. If in Fig. 1 the brush is put on the neutral point and the commutator rotated then as bar *1* slides from under the brush, it continually diminishes the area in contact with the brush, i. e., the resistance between the bar and the brush is acting as a continually increasing back electro-motive force tending to force the current through the coil *1-2*. If the self-induction of the coils should not be great, this back electro-motive force will be suf-

ficient to commutate the current before the bar *1 l*eaves the toe of the brush. If the brush is rocked back from the neutral an electro-motive force from the stray field is obtained which is opposed to commutation, but if the opposed electro-motive force is not too great the carbon brush may still run without sparking. It will be seen, therefore, that with a commutating field and the carbon brush as well, matters are very much easier. The ordinary practice with a generator is to rock the brush as far forward at no load as it will go without sparking. If it is put too far forward the electro-motive force in the coils will cause eddy current in the brush and it will begin to glow. If it is not too far forward, the contact resistance is sufficient to prevent excessive current. As the load on the machine is increased the commutating electro-motive force which is there is needed more and more until (perhaps at half load) the commutating electro-motive force may be just sufficient to commutate the current without the aid of the contact resistance. If the load be further increased, the commutating electro-motive force is not quite sufficient, but with the additional effect of the contact resistance commutation occurs without sparking. The amount of contact resistance between carbon and metal is therefore a matter of great importance.

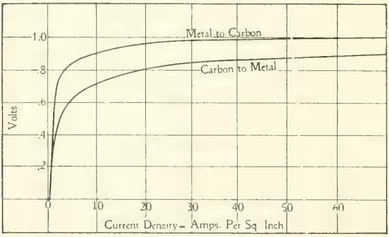

FIG. 2—BRUSH DROP—DIRECT-CURRENT

POTENTIAL DROP BETWEEN BRUSHES AND COMMUTATOR

The curves in Fig. 2 give the value of the voltage drop between the metal and carbon for different current densities. It will be seen that it is greater when the current passes from metal to carbon than when it passes from carbon to metal. Fig. 3 shows how the voltage drop is affected by the pressure of the brush. When the current density is zero the potential drop is of course zero, but it rises very quickly as the density is increased to about ten amperes per square inch. The curves in Fig. 1 show that the drop tends to become uniform for great current densities. At forty amperes per square inch the voltage is about 1 for metal to carbon and about 0.9 for carbon to metal. If the current density is doubled beyond this point the drop is not very much more. This is a very extraordinary phe-

nomenon and one which is but little understood. It would appear as if there was a very short arc between the carbon and the metal and that this arc was capable of exerting a back electro-motive force of about one volt. If instead of a direct current an alternating current is used, the phenomenon is somewhat changed. The potential drop for high current densities continually increases as shown in Fig. 4. As long as the commutator rotates, the potential drop follows the course shown by the full line, but when stationary the drop is as indicated by the dotted line, i. e., it is an ordinary case of resistance. Apart from the contact resistances, there is always some true resistance in the carbon itself, but this is usually very small in comparison with the contact resistance.

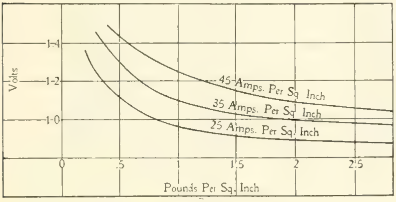


FIG. 3—SHOWING HOW BRUSH DROP IS AFFECTED BY VARIATION IN PRESSURE

If the machine under consideration were a motor instead of a generator the current would be flowing in the opposite direction, and it would be necessary to rock the brushes back in order to get the correct commutating electromotive force. It thus comes about that generators operate best with the brushes rocked forward, and motors with the brushes rocked backward.

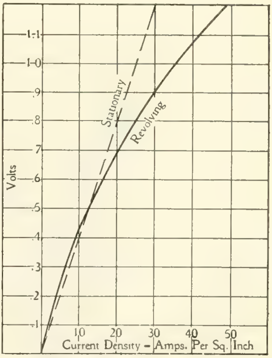


FIG. 4—BRUSH DROP—ALTERNATING-CURRENT

## ARMATURE REACTION

Unfortunately the self-induction of the armature coil is not the only trouble met with. The currents in the armature distort the magnetic field so as to interfere with the strength of the commutating field. Fig. 5 shows the distortion of field produced in the field magnets by the armature. The curve *A* gives the field form at no load. The curve *B* shows the field which would be produced by the armature currents operating by themselves. When a

generator is operating on load a combination of *A* and *B* results as shown by curve *C*. The dotted portion *D* shows the form *C* would

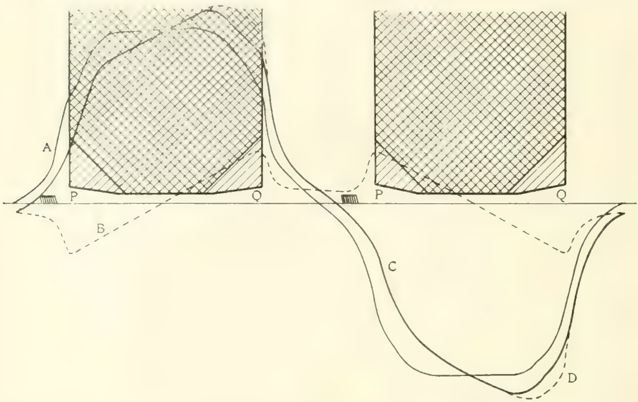


FIG. 5—DISTRIBUTION OF FLUX IN FIELD AND ARMATURE AND DISTORTED FIELD RESULTANT

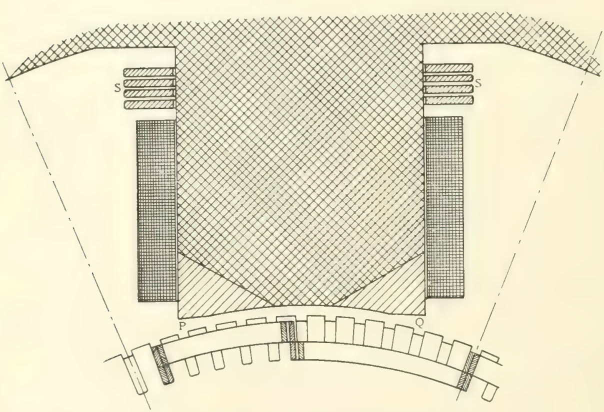


FIG. 6—ARRANGEMENT OF SERIES WINDING AND POLE FACE TO GIVE STRONG FRINGING FIELD ON HEAVY LOAD

assume if it were not for the fact that a part of the punchings of the poles are cut away at the corners, leaving the corners highly

saturated. It may be seen that the fringing field which is relied on for getting the commutating electro-motive force is considerably diminished by the armature distortion. This will be more or less the case as the main field is made stronger or weaker in proportion to that produced by the armature. Thus it follows that the field ampere-turns should always be made great as compared with the armature ampere-turns in the ordinary commercial machine in order to effect good commutation. Ordinarily, the field will have two or two and one-half times as many ampere-turns on it as the armature.

*Use of series winding*—One means of preventing the commu-

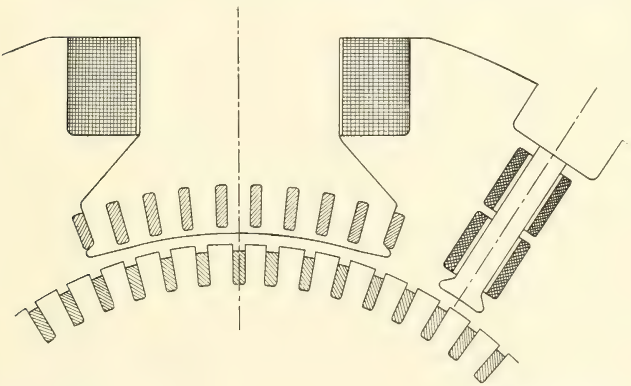

FIG. 7—SHOWING METHODS OF OVERCOMING FIELD DISTORTION BY COMPENSATING WINDING AND BY COMMUTATING POLE

tating field from being very much weakened when load comes on is to put a heavy series winding around the poles and at the same time magnetically saturate the pole face and the armature teeth in order to make the fringing field fairly strong. This arrangement is shown in Fig. 6, which illustrates an arrangement commonly employed in traction generators. The iron at the corners of the poles is cut away, leaving just sufficient iron to carry the working flux. As the load comes on the armature tends to weaken the pole at the point $P$ and strengthen it at the point $Q$. As the iron is very highly saturated at the point $Q$ it is impossible to increase the flux very much more there. The series winding shown at $S$ supplies a large number of ampere-turns on load, and tends to bring up the field at

the point $P$ even higher than it was at no load, so that the fringing which occurs from the side of the pole is not weakened as it would be if the series winding were not employed. This plan, in conjunction with the use of the carbon brushes, has been very successful. Hundreds of large traction generators, up to 3 000 kw capacity have been made on this plan and proved eminently satisfactory. The plan is a good one because it is extremely simple; the series winding tending to help the commutation and give the required rise in voltage at the same time.

*Use of distributed field winding*—The distortion of the field by the armature may be more effectually prevented by adopting a compensating field winding wound through holes in the pole face as shown in Fig. 7. This was proposed by Prof. Ryan many years ago, but did not come into general use on account of its expense and complication. In special cases, however, as in very high-speed generators and motors, in which commutation is particularly difficult, this compensating field can be employed with advantage. The winding is arranged so as to produce a field which is equal and opposite to the armature. For every ampere-turn on the armature tending to produce distortion of the field there has to be an equal opposite ampere-turn in the compensating winding. These windings are sometimes employed in connection with commutating poles.

*Use of commutating poles*—The commutating pole, Fig. 7, consists of an iron projection between two main poles. Its object is to produce a field which will commutate the current in the same manner as described in connection with Fig. 1. The advantage of the commutating pole is that the strength of the commutating field can be made proportional to the amount of current to be commutated, and moreover the brush will always be on the neutral point. The commutating pole must be wound with the number of ampere-turns rather greater than the ampere-turns on the armature. It will be seen that the armature itself always tends to produce a field which is opposed to commutation and if an iron projection is put on as shown in Fig. 7 without any winding on it, the commutation is made very much worse than without it, but if the pole be wound with enough ampere-turns to overcome the magnetizing effect of the armature and a few extra ampere-turns sufficient to produce a commutating field be added, the commutating conditions become so good that even metal brushes may be used. Most makers still employ metal brushes in high-speed direct-current machines, on account of the difficulty of running a carbon brush on a commutator at a high speed if the commutator is out of true. The metal brush,

being soft and yielding, makes good contact even under bad running conditions and by the use of commutating poles good commutation can be obtained. There is still, however, a drawback to the metal brush and that is, that it wears the commutator more rapidly than the carbon brush and is itself worn away. A brass wire brush six inches long will be worn completely away in two or three months, whereas a carbon brush of the right quality hardly wears the commutator at all, and will last for several years under good conditions.

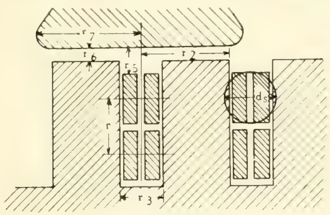


FIG. 8

In calculating the strength of field required to commutate properly in any given case, it is necessary to consider the duration of the commutating interval, and also the magnetic permeance of the path around the armature coil. It is evident that the more the armature coil is buried in iron, the greater will be the magnetic flux set up by the current in the coil, and the greater must be the commutating field.*

In machines without commutating poles it is of course important to keep the self-induction of the coil as low as possible. A very good plan is to make what is called a short chorded winding. This is shown in Fig. 10. By employing a short chord the total cur-

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*If the simple case of the straight slot shown in Fig. 8 be assumed, the magnetic effective permeance of the path across the slot per centimetre length of slot is

$$L_1 = 1.25 \left( \frac{r}{3\, r_3} + \frac{r_5}{r_3} \right)$$

All dimensions are in centimetres.

The permeance of the path from the top of one tooth to the top of the other is

$$L_2 = 0.92 \log_{10} \left( \frac{\pi\, r_2}{r_3} \right)$$

The permeance of the path from the top of the slots to the commutating pole and back again is approximately

$$L_3 = 1.25 \, \frac{r_7}{2\, r_6}$$

When the air gap between the teeth and the commutating pole is small compared with the width of the commutating pole, $l_2$ may be left out of account altogether.

To these must be added something for the flux around those parts of the coil which lie outside the slot. With ordinary diamond-shape

rent in each slot is commuted in two independent halves instead of being commuted all at once, so that the electro-motive force set up in the coil is not as great as if a full pitch winding were employed.

*Inductor effect*—Beside the self-induction and the field distortion, there are other matters which must be closely attended to if a machine with good commutation is to be produced. One source of trouble is what may be called "inductor effect." This is the change of the total permeability of the magnetic circuit through the armature by the changing position of the slots. It is illustrated in Figs. 11 and 12. If the punching depicted in these figures be rotated it will cause the total flux through the armature to increase and decrease periodically as the teeth take up different positions in rela-

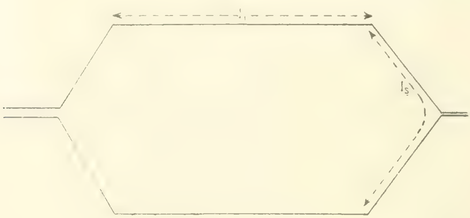


FIG. 9 FORM OF COIL USED IN SHORT CHORD WINDING

tion to the poles. In the position shown in Fig. 11 there are five teeth under the pole, whereas in the position shown in Fig. 12 there are only a little over four teeth under the pole. This increase and decrease of the flux is sufficient to generate alternating electromotive forces in the coils under commutation and cause trouble.

coils as shown in Fig. 9, this allowance may be taken as

$$L_e = 0.46\,\frac{l_s}{l_i}\left(\log_{10}\frac{l_s}{l_i} - 0.2\right)$$

where $l_s$ and $l_i$ are the lengths shown in Fig. 9 and $d_s$ (see Fig. 8) is the diameter of a circle whose circumference is equal to the perimeter of the conductors forming one coil. If the sum of all these permeances be taken as

[illegible]

then the strength of the commutating field is given by the expression

$$B = 0.8\,L \times \frac{\text{amperes in slot}}{p\,b\,c}$$

where $B$ stands for the flux density in the air gap under the commutating pole in lines per square centimetre and $p$, $b$ and $c$ are the distances in centimetres shown in Fig. 10.

$p$ is the pitch of the teeth on the circumference of the armature.
$b$ is the pitch of the brushes on the same circumference.
$c$ is the pitch of the commutator bar on the same circumference.

This is best cured by beveling the poles. Another source of trouble is irregularity in the self-induction of different armature coils. Where there is a great number of coils per slot there is always a

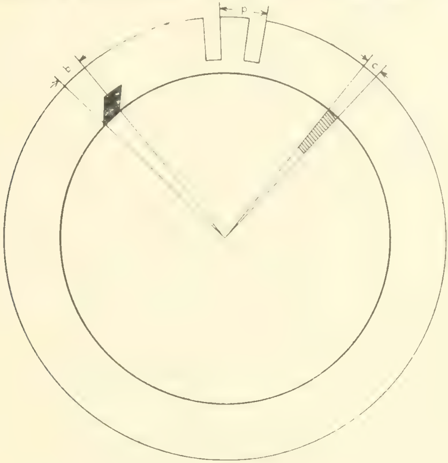


FIG. 10

difference in the effective self-induction between the last coil in the slot to be commutated and the others, owing to the effect of mutual induction between the coils in the same slot so that the commutating field which may be strong enough for one coil is not strong enough

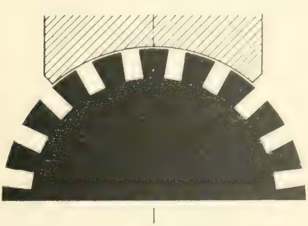

FIG. 11

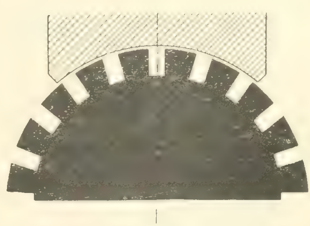

FIG. 12

SHOWING HOW PERMEABILITY OF MAGNETIC CIRCUIT IS EFFECTED BY RELATIVE POSITION OF SLOTS AND POLE

for another. This trouble generally produces marking at regular intervals around the commutator. If the voltage between bars be too high, or the number of slots per pole too small, trouble is encountered for obvious reasons. To make a machine operate at its

very best it is very important to preserve symmetry in its various parts. The very greatest care should be taken with the spacing of the poles, the spacing of the brushes and the air-gap under each of the poles.

### COMMON SOURCES OF TROUBLE

In Table I most of the common sources of trouble in commutation have been collected under headings as shown. These troubles are numbered from one to thirty-six for the purpose of easy

TABLE I—CAUSES OF BAD COMMUTATION

| | | | |
|---|---|---|---|
| MECHANICAL EFFECT IN | COMMUTATOR | 1 | Chattering. |
| | | 2 | Changing of facets. |
| | | 3 | Brushes not touching commutator. |
| | | 4 | Vibration of brush gear. |
| | | 5 | Tension too great. |
| | | 6 | Bad connection to brushes. |
| | | 7 | Copper on brushes. |
| | | 8 | Bad brushes. |
| | BRUSH GEAR | 9 | High bars. |
| | | 10 | High mica. |
| | | 11 | Bad spacing of bars. |
| | | 12 | Commutator not true. |
| | | 13 | Vibration of commutator. |
| | | 14 | Dirty surface. |
| | | 15 | Short-circuits between bars. |
| DEFECT IN ERECTION | | 16 | Bad spacing of brushes. |
| | | 17 | Bad spacing of poles. |
| | | 18 | Irregularity in air-gaps. |
| | | 19 | Irregularity in windings or cross-connections. |
| | | 20 | Intermittent short-circuit in windings. |
| | | 21 | Intermittent open circuit. |
| | | 22 | Wrong polarity of poles. |
| | | 23 | Partial short-circuit in field coils. |
| | | 24 | Bad contact in brush arm. |
| DEFECT IN DESIGN | | 25 | Self-induction of armature coil. |
| | | 26 | Too high voltage per bar. |
| | | 27 | Irregularity in self-induction of coils. |
| | | 28 | Too great field distortion. |
| | | 29 | Inductor action of teeth. |
| | | 30 | Brush capacity too small. |
| | | 31 | Brushes too wide. |
| | | 32 | Brushes too narrow. |
| | | 33 | Brushes too high conductivity. |
| IMPROPER OPETATION | | 34 | Brushes rocked to wrong position. |
| | | 35 | Irregularity in or unbalanced alternating-current voltage supplied to rotary. |
| | | 36 | Bad adjustment of commutating winding. |

reference in the remarks which follow. Suppose that a generator is put on test and it is found that it sparks. How is one to find out what is wrong with the machine?

First look out for mechanical troubles. These can generally be detected on inspection. If it is not a mechanical trouble, does the machine spark at no load with the brushes on the neutral position? If the machine sparks at no load it is probable that the trouble arises from Nos. *16*, *17*, *18*, *19*, *20*, *21*, *22*, *23*, *27*, *29*, *31* or *35*.

The spacing of the brushes and air-gap can be measured and thus dispose of *16*, *17*, and *18*. No. *19* can in general be detected by resistance measurements. No. *22* can be tested with a compass needle. No. *23* can be detected by measuring the resistance of the field coils. No. *27* usually shows itself by marking the commutator at irregular intervals. No. *29* can sometimes be cured by beveling the poles. No. *35* can often be detected by measuring the alternating-current volts. If the machine does not spark at no load, but does spark on load, the effect of rocking should be noted. If at each degree of load it is possible to find a non-sparking position, but the position changes easily with load, the circumstance points to No. *25*, *26*, *27*, or *28*. If for some degree of load it is not possible to find a sparkless point and if the mechanical operation of the brushes and commutator is perfect, each point from *16* to *36* must be gone over and the trouble found by a process of elimination. A good general plan is to find the limiting positions of sparking on the different brush arms when the brushes are rocked forward or backward at no load and for different loads. This often points to dissymmetry, which can be remedied. Another plan is to isolate all the brushes and connect a dynamometer between pairs of brushes of the same polarity. This will throw a light on any alternating or direct-current flowing between the brushes, which, if present, can be further investigated. The question whether it is an alternating or direct current is of course important. Observation of the marking of the commutator should not be neglected.

In all cases where it is desirable to have a machine commutating under the best conditions, all the causes of sparking mentioned in the table should be eliminated. After the commutator has been finally turned down, all copper dust should be very carefully blown off the armature and brush holders and the brushes should be well bedded in with fine glass paper. The tension of each spring should be adjusted so that it is sufficient to prevent chattering, and also sufficient to overcome the friction of the brush in the holder. If the machine is now run light for a few hours the brushes will acquire a high polish, which increases the contact resistance and enables the brushes to be rocked further forward at no load than when the surface of the brushes is rough and the tension of the springs is too great.

# AN EVENT IN ELECTRICAL DEVELOPMENT*

PH. A. LANGE

A FEW weeks ago, a gentleman asked me what I considered to be the most important event in the history of electrical development. In reply I stated that to my mind there were three events of almost equal importance, the invention of the incandescent lamp; the discovery of the electric motor, i. e., the reversibility of the dynamo, and the invention of the induction motor.

Since then, I have given more thought to the matter, and my opinion has changed. If asked the same question to-day, I should answer, the advent of the young man with a college training into the electrical field. In the early days of the electrical industry, if it was desired to lay out the wiring for lighting a city, the process adopted by the Edison Company was as follows:

A huge map was prepared, showing the location of the streets and the position of the houses where current was to be supplied. On this map, a spool of German silver wire was located wherever a house was to be supplied with lights. Each spool had a resistance proportional to the resistance of the lamps in the house. Wires corresponding to the feeders to be actually used were stretched along the streets, and the German silver spools were connected to these wires. Current was obtained from a small Daniel battery, and distributed to the different spools through the wires. A professor then sat in front of the map and measured with a galvanometer the drop along each of the wires. From his measurements, the proper wires for running along the streets of the city could be determined.

After this system had been in use for two years or more, Mr. F. J. Sprague joined the Edison forces. He was the first man among us with a technical education who had made a special study of electricity. He quickly showed how to calculate the drop in feeders without laying out a whole city in miniature, determining in a few hours or minutes results which had previously required weeks of experimental work and a considerable financial outlay.

This is only one of many cases which could be cited where the technically trained man has shown the possibility of predicting results theoretically which previously had to be determined experimentally, at very great expense, and I am convinced that the entrance of the college man into electrical engineering has been the most important event in the history of the industry.

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*Extract from an address delivered at a dinner of the Engineers' Club of Manchester, England, March 15, 1907.

# ENGINEERING COURSE OF THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

H. D. SHUTE

Assistant to the Second Vice President

AT this time of year a number of young men who will graduate from our leading technical schools are considering the advisability of entering the employ of one or another of the large electrical manufacturing companies. Such men may be helped by and interested in a brief account of the course which has been established by the Westinghouse Electric & Manufacturing Company for the post-graduate development of engineering students.

In the early days when the Company was comparatively small, we began in a somewhat unsystematic manner to take into our organization each year a few of the graduates from the leading technical schools. At that time no regular plan was followed in the treatment of these young men. In almost every case each man was selected to do some particular engineering work and almost immediately upon his arrival took a definite and fixed position in the Company's engineering or Works organization. As the Company expanded, need was felt for men to be used in our Construction Department, in our Engineering and Designing Departments, in our sales force and in those departments of our shop organization where a kowledge of the fundamental engineering principles was necessary. About 1890 a definite plan was put in force by which about thirty or forty engineer graduates were each year taken into our Works organization. These men were not selected for any particular ultimate position but were chosen for their general average ability, it being the Company's purpose that they would be developed in our manufacturing and testing departments for ultimate positions with the Company, such positions to depend upon the ability and temperament which the men would display during their period of preliminary shop training. No definite length of time for this so-called "Student's Course" was arranged. The men were placed nominally under the charge of the chief of the Testing Department. They were not, however, immediately placed in our testing room, but as they reported for work were placed in the various Works Departments where they wound armatures, assembled transformers, chipped castings and did other similar work. As they developed and as the need came, they were trans-

ferred to the Inspection and Testing Departments and finally through a somewhat haphazard scheme according to the general rule of the survival of the fittest were promoted to positions involving more specific engineering work. This plan, it will be noted, was more or less hit or miss.

Under this system the high caliber men quickly shone forth, were recognized and given positions equal to their ability. The general run of the "students," however, did not receive that oversight and careful training which would lead to the greatest good in the way of development for the greatest number.

As our business grew, our needs for designers, general engineers, expert technical salesmen, commercial office men and superintendents largely increased until about 1900 it became evident to our executive officers that a definite course for engineering students was necessary to the development and growth of our organization.

In making a decision as to the proper engineering apprenticeship course to install in our Works, the following alternative plans were available:

1. That the entering technical graduates should be taken directly into our Engineering, Construction or Commercial Departments, without being put through a course in our shops.

2. That these young engineers should be taken directly into our various Testing Departments without being given any preliminary manufacturing work, and that their whole development should be obtained by means of our Transformer, Detail, Motor or Dynamo Testing work.

3. That these young men should be first placed in our manufacturing departments, where they would receive definite and direct experience in the manufacture of our product, such work to be supplemented by a course in our various Testing Departments.

4. That these men should be given a course in our manufacturing departments, followed by a course in our Testing Departments, to be finally supplemented by a course either in the Engineering, the Commercial, or the outside Construction Department.

The decision of our officers was in favor of this fourth plan. This decision was reached principally by a consideration of the question as to the class of men that was needed in our business and by observation of the results secured by the methods previously employed.

We were and still are looking for engineers to deal with our designing problems. We are looking for competent men to erect and

operate our apparatus in our customers' plants, and we are looking for technically trained salesmen and commercial office men. Men to fill such positions should have a knowledge of the way electrical machinery is made, should get in close touch with workmen and skilled mechanics in order that at a later time they may know how to direct such men. They should also know, through the actual testing of the apparatus, what the various appliances will do in pactice.

The school period of the engineer is planned by our educators for the acquisition of fundamental principles upon which to build the foundation upon which his later engineering career shall rest. Our course has been planned with the idea of building upon the foundation gained at the technical school the first story of such an engineering career.

The course as devised by us and as at present in practice is nominally of two years' duration. We have nominated two years as the length of our course, believing that the average graduate of a technical school should take that much time in his general development before choosing finally his particular engineering career. In the majority of cases at this present extremely busy period, very few of our young engineers have the advantage of remaining on the course for the whole two years, but before that time are given permanent positions with this Company or find satisfactory positions with outside manufacturing or engineering concerns.

Upon entering our Works, the young man is placed in one of our minor manufacturing departments and is put to winding coils or assembling brush holders or other details of manufacture. At regular and frequent intervals he is transferred from one department to another of our manufacturing sections, before entering assembling departments where he obtains practice in the building of generators, motors, rotary converters and transformers.

The value of the training obtained during this Works period is by no means confined to the knowledge obtained of the details of the manufacture of the apparatus, nor to the practice obtained in the handling of tools. The principal benefit derived from this part of the course is due to the fact that during these months the young engineer comes in actual contact with labor. All engineers, if they expect to achieve prominence in their profession, must sooner or later be called upon to deal with problems arising from the relations between employers and labor. Every engineer probably hopes sooner or later to be an employer. When that time comes the young man will find that the direct knowledge gained of the way skilled and unskilled workmen think will be of inestimable value to him.

Having passed through the shop portion of his course, the engineer is transferred systematically through the various Testing Departments where he is given an opportunity to test high tension transformers, detail apparatus, such as switches, circuit breakers, controllers and wattmeters, and is finally placed in the Dynamo and Motor Testing Department. At another period he is transferred, as a part of his course, to either the Engineering, Commercial or Construction Departments. If, after trial in such department, it is found that his qualifications are such as to make him a valuable man in that particular department and if he feels that the work therein is of such a nature that he will make a success of it, he is given a permanent position and an opportunity to further advance and develop.

The results which have been accomplished by this general policy in connection with the development of engineering graduates and the results achieved by our present course, which has now been in operation nearly ten years, may be conservatively stated as extremely satisfactory. In making this statement I do not imply that the results have been satisfactory from the Company's standpoint alone since from our records it is plainly shown that a very large majority of the young men who have taken our engineering course have profited thereby in every way in the advancement along their engineering and commercial careers.

That the training afforded by our engineering course and the general treatment accorded to the young engineer by our Company is satisfactory, is directly evidenced by the fact that a very large percentage of the engineering apprentices ultimately accept regular positions with us. Many of our managers, heads of departments and our principal engineers entered our employ as engineering apprentices and have "risen from the ranks."

The course as at present established does not include as an integral part any classes, lectures or similar adjuncts. The course has been planned primarily for the purpose of giving the young engineer, through actual and practical experience, a training which will make him essentially self-reliant. Our engineers, however, have themselves established at a nearby town where most of them live, an Electric Club. Here are available classes and lectures, as well as social features, including dances and amateur theatricals. The men who have the immediate management of the Club and many of its various activities, are changed from time to time in order to give, as far as is practicable, an opportunity to as many of the apprentice engineers as possible to gain experience in the management and operation of these enterprises.

The young man now about to graduate with an engineering degree has a decision to make and in making this decision actual conditions in the world of work must be considered. Only a small percentage of these young engineers can hope for professional careers. The majority will ultimately, through opportunity and temperament, become fixed in administrative and commercial positions. Each graduating engineer, therefore, must decide whether he shall launch himself at once into an independent career or shall by still further training with an already organized commercial concern guide his steps into the life work best suited to his own individual mental and physical equipment. The greater number of these young men must consider the material advantages likely to ultimately accrue in following the one or the other course.

Usually a man takes a technical course at our colleges because he likes mathematics, science or engineering. Since ordinary engineering courses have in view principally the idea of imparting fundamental engineering principles, the average man upon graduation is apt to be somewhat narrow and lacking in the broad general knowledge of business principles. It is the object of our engineering apprenticeship course not only to place the young men in touch with workmen and commercial manufacturing experience but by placing upon them the responsibility for the accomplishment of real work to build up in them a keen sense of commercial responsibility. They must build apparatus which is to be sold; complete commercial tests; design apparatus which must meet actual needs; install plants; erect apparatus, or negotiate for and close contracts covering apparatus which is to do work in the world. These engineering apprentices are no longer in the college class room or laboratory where the results of mistakes in calculations or judgment mean no particular personal discredit. They are now in direct contact with the working world. They must think clearly and self-reliantly and the effect of errors due to lack of ability, study or sound judgment become quickly apparent and are brought home to them sharply. It is by such treatment that we aim to supplement the college course and to broaden the view point of the young engineer.

# THE STANDARDIZING LABORATORY—VI

## A SUBSTITUTE FOR THE SECOHMMETER IN INDUCTANCE MEASUREMENTS

H. B. TAYLOR

THE function of the secohmmeter is to increase the sensibility of bridge measurements of capacity and inductance by continual quick repetition of the impulses received by the galvanometer due to the discharge of the condenser or of the magnetic field as the case may be. In the original Ayrton and Perry design, which is the familiar form, the secohmmeter consists of two rotating commutators, each having two moving contact pieces and four brushes. One commutator reverses the connection between the bridge and battery and the other reverses the connection between bridge and galvanometer at the proper instant to keep the impulse received by the galvanometer due to the discharge current always in the same direction. The effect is to increase the sensibility enormously, for the resulting pulsating current to the galvanometer is practically continuous when the commutators are turned rapidly, so that a steady deflection will occur as long as the bridge system is unbalanced.

A convenient device to take the place of a rotating secohmmeter in comparing coefficients of self-induction can be arranged from common and inexpensive material. Two ordinary reversing switches could be used to make the same connections as the secohmmeter, but they could not be operated rapidly enough to be of much benefit. Relays of the kind used on telephone switchboards can be connected as double-pole, double-throw reversing switches and will operate well at speeds as high as one hundred and twenty reversals per second. Telephone relays are made with different numbers of contacts. For this purpose six connections are required, two of them being the metal strips which can be made to vibrate at the outer end between two fixed contacts on each side of them. Normally the middle tongues make connections with one pair of fixed contacts. If direct current is applied to the relay magnet its armature is attracted and transfers the contact to the other pair. On alternating current at frequencies of sixty cycles and lower the armature responds to the reversals of line e.m.f., changing the connection twice during each cycle. Direct current with an interrupter in the circuit can be used when alternating current is not available.

A pair of such relays has been used extensively with a bridge and standard inductances, connected as shown in Fig. 1. High sensibility has been obtained at all times and the arrangement is more convenient than a secohmmeter in several ways. Dust-proof caps cover all working parts, so that the apparatus can be mounted out of the way and requires no attention. The relays are connected two in series, across the 25 cycle 220-volt lighting circuit. All that is necessary to set them in motion or stop them is to close or open a key switch. The noise made is rather objectionable, but since

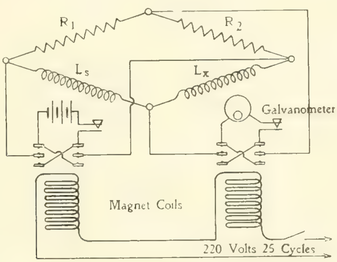


FIG. 1—DIAGRAM OF CONNECTIONS FOR INDUCTANCE TESTS USING RELAY ARRANGEMENT

they can be started or stopped instantly, it is never necessary to keep them connected very long at a time.

This arrangement would not be a suitable substitute for the secohmmeter in measurements of capacity because the exact instant of making contact on the two sides, and the quality of the contact at each reversal could not be known definitely enough. For inductance measurements those considerations are not important.

# EXPERIENCE ON THE ROAD

## SOME TROUBLES OF DIRECT-CURRENT MACHINES AND THEIR REMEDIES*

W. H. EAGER
of the Whitman & Barnes Mfg. Co., Chicago, Ill.

THE ability to make a brief but thorough observation of conditions at hand, to detect the reliable from the unreliable information obtained, to correctly "diagnose" from the "symptoms" and thereby discover the cause, are essentials of the "Trouble Engineer."

The notes which follow were made by the writer in connection with difficulties experienced in central station work with apparatus of various makes. No attempt has been made at classification other than that the notes are here presented in chronological order.

*Sparking at commutator*—The first case is that of a 100 kw, 125 volt generator accused by the operator of continuous and vicious sparking. It was found that no sparking occurred when the commutator had been newly turned but that sparking began and increased from that time until it became necessary to turn off again. Inspection of the machine showed that the commutator was smooth but that the brushes were chattering badly. The commutator was very dirty and this caused the brushes to adhere to the commutator momentarily, thus causing a continuous vibration or chattering. The remedy was to clean the commutator and lubricate it with a few drops of oil.

*A broken lead*—A 20 hp variable speed motor ran nicely at about two-thirds maximum speed. When load was thrown on it "flashed over." At times the motor would carry full-load, but any sudden change of load or speed made trouble. The machine was tested for short-circuit by the use of a lamp and cord. Next the insulation was tested and found to be in good condition. The designers were interviewed to discover whether any feature of the machine inherently tended toward sparking. The trouble was finally found to be caused by a broken lead which made contact at low speeds, but which pulled apart at high speeds or by magnetic influences at sudden load changes.

*Irregular Neutral Point*—A 250 kw, 550 volt generator sparked at the brushes on one brush stud only. Shifting the rocker arms

*Based on a lecture delivered before The Electric Club.

removed the sparking at this stud, but at the same time produced sparking at all the others. Geometrically considered the stud was found to be properly placed; but, owing to the slight displacement of the corresponding pole-piece, the brushes of this set did not come on the neutral point when the remaining brushes were properly placed. The sparking was entirely eliminated by setting the brushes on the neutral point by the voltmeter method, although this necessitated placing this set of brushes out of place nearly one-eighth inch by the tape.

*A grounded armature*—Another motor, which had been operating for a number of years under a very uniform load, suddenly began to blow its fuses. The capacity of the fuses was increased until it exceeded the normal rating of the motor by fifty percent. The commutator flashed badly and the machine heated quickly. The belt was taken off and the motor allowed to run idle, but even then it took a large current. This indicated what was afterwards found to be the case, a badly grounded armature.

*Another broken lead*—A generator was flashing badly at the brushes and burning the commutator, due to an armature lead which had broken off near the commutator. A temporary repair was affected by "dead ending" the defective coil and soldering together the commutator bars at the point where the break occurred. Where a break of this nature is present, but not readily discernable, it may be located by testing with a lamp and cord.

An open lead in a motor armature produces results similar to the same trouble in a generator. If the machine can be run without burning the commutator too badly, a means is thereby acquired of readily discerning the location of a broken lead. When run a short time, it will be found, after stopping the motor, that two insulation strips have been burned. The broken leads will be found to belong to the bar which is behind the burned insulation; "behind" being a term based on the assumption that the direction of rotation is forward.

*Short-circuited or reversed coils*—A trouble, caused by conditions differing from the last case but sometimes producing a similar effect upon the operation of a machine, is that of a short-circuited or reversed coil. A pen-knife held suspended midway between the poles will be jerked as the defective coil passes beneath it.

The foregoing examples are for the most part simple in cause and effect. Scarcely one, however, had it been neglected, but would have continued from bad to worse. Breakdowns of more serious

nature, such as burned out armatures, short-circuited armatures, broken leads and the consequent burning of commutators, reversal of field or "bucking over" as it is more generally known, "flats," vibration and noise, etc., are generally made possible through the neglect of smaller matters such as have been enumerated.

Troubles may be prevented to a large extent by properly heeding such precautions as the following:—

Machines should be located in dry places, free from dust and dirt. If the latter is impossible, an enclosed machine should be used.

New machines shipped during damp or cold weather should stand several days before current is applied to them, so that they may be dried after the sweating to which they are liable.

All connections should be tight, brushes properly fitted to the commutator, and oil rings working properly. After a machine is started it requires supervision. Keep it clean. A cotton cloth neatly wrapped on the end of a flat stick is better than waste on the commutator. To polish a commutator use sandpaper, never emery cloth. An air blast readily disposes of dust. Keep oil away from parts that are not supposed to be oiled. Oil rots and destroys the insulation. Never let a machine spark. If it does, stop at once and locate the trouble, but do not let a machine keep on sparking day after day. It eventually means a new commutator and before that an endless supply of brushes.

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**Sales Contracts**

The management of the JOURNAL is to be congratulated upon securing for its readers from Mr. Brennan a summary of his valuable work relating to sales contracts, a part of which appears in this issue. Contracts are usually drawn by representatives of the parties thereto, who ordinarily are handicapped by lack of experience and knowledge of the governing laws, and by reason of the fact that after being signed the papers are usually turned over to others for fulfillment, the opportunities for gaining knowledge by experience are limited.

Mr. Brennan's article fulfills a long felt need in that it places within reach of those who draw sales agreements the fundamental laws and customs relating thereto, in a clear, concise manner, readily comprehended by those without special legal training, and a careful reading thereof cannot fail to make evident its value as a guide which will enable contracts to be drawn in a manner to avoid legal pitfalls, with the intention so clearly expressed as to enable those who come after to fulfill them without the misunderstandings which are always annoying and frequently expensive to one or both parties.

Regarding "mutual assent" Mr. Brennan has written something which is well worth emphasizing, as experience teaches that probably more trouble arises from a lack of application of the principles he so clearly sets forth than from any other one cause.

It sometimes happens that ambiguous clauses are inserted by one of the parties for the express purpose of deceiving or gaining an advantage over the other party. Mr. Brennan points out the futility of such procedure from a legal standpoint, and experience has demonstrated that such clauses are valueless from a practical standpoint and usually act as trouble breeders. More frequently carelessness in the use of phraseology or failure to incorporate in the contract matters which have been agreed upon and mutually understood are responsible for trouble between contracting parties. This might not be so serious if the individuals who draw up the papers had the whole responsibility of the execution of the terms thereof; the

"heirs, successors, administrators and assigns," are the ones who have to be considered, and they should be placed in a position to execute the terms of the agreement with a perfect understanding of the intention, and this can only be accomplished by a clear expression of the mutual understanding on the part of the ones who draw up the papers and by the exercise of due care in taking proper steps in case changes are made.

The issues of the JOURNAL containing Mr. Brennan's article should be carefully preserved and frequently consulted by those who are responsible for the drawing of sales contracts, and the result will be that many of the faults which exist in the greater proportion of the contracts of to-day will be eliminated.

W. F. FOWLER

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**Electric Train Staff System**

It is a peculiarity of the two great branches of the Anglo-Saxon race that each of them has been a trifle slow to adopt the other's methods, although of late years this is less marked than formerly. This feature can be noticed in railroad signaling as well as in other branches of the mechanical arts. Our English cousins have been very conservative in adopting the systems of power interlocking and automatic block signals so generally used in this country, while the railroads of the United States have been equally slow in appreciating the many advantages of operating single track lines by the electric train staff system described in Mr. Patenall's article in this issue of the JOURNAL.

In England the omnipotent Board of Trade has declared that unless the staff system or its equivalent—the tablet system—be employed for the operation of a single track line, only one train is permitted to run on that line. In this country the staff system is in use on less than five hundred miles of railroad, the balance of the single track lines being operated under time card rules and the telegraphic train order system around which additional safeguards in some form of block system are occasionally thrown. The main objections raised by the railroad companies to the use of the staff system are two-fold; first, that it increases the cost of operation owing to the number of operators required; and secondly, because they doubt the practicability of taking and delivering the staffs or tickets at high speed. The first objection vanishes as traffic increases, besides being equally true of any controlled manual block system, and

the second seems to be without an entirely logical basis when we consider the number of mail sacks which are caught and delivered each day at speeds running as high as sixty and seventy miles an hour. As a modern train staff weighs about six ounces while a mail pouch will occasionally run over fifty pounds, it seems reasonable to suppose that if the catching and delivering could be effected in no other manner the staffs might be enclosed in mail sacks.

The slowness with which the staff system is growing in popularity in this country may therefore be at least partially ascribed to the racial peculiarity previously mentioned.

J. S. Hobson

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**High-Speed Steel Tools**

The article on "High-Speed Steel Tools" in the May issue of the Journal, contained the following classification of steels:

A—Carbon—chromium—tungsten
B—Carbon—chromium—molybdenum
C—Carbon—chromium—molybdenum—tungsten
D—Carbon—tungsten—nickel.

Since the publication of this article a very interesting communication has been received from Mr. F. W. Taylor, ex-president of the American Society of Mechanical Engineers, in which he points out that the investigations made by Mr. White and himself and which included exhaustive tests on all of the above groups showed the combination of carbon—tungsten—nickel to be unsuitable for high-speed tool steels, and, further, that any combination in which nickel enters in or from which chromium has been omitted is equally unsuitable.

The division of high-speed tool steels into the four classes given was a purely nominal one and was based upon the outcome of a series of analyses made in 1904-1905 of twenty-two brands of commercial steel, both American and foreign, one of these being found to contain the combination of carbon—tungsten—nickel, as stated. Subsequent trial of this steel under actual shop conditions, proved it to be inferior to most of the other samples in the amount of work performed.

We are, therefore, very glad to receive confirmation from so recognized an authority, as Mr. Taylor, showing that the conclusions formed by us at that time as a result of analysis and trial were correct.

E. R. Norris

# STORAGE BATTERIES*

V. KARAPETOFF

Assistant Professor of Experimental Engineering, Cornell University

## PROPERTIES OF STORAGE BATTERIES

*COMPARISON to Water Storage Tank*—Storage batteries (also called electric accumulators) are devices used for storing electrical energy, which may be delivered at a later time. The part which storage batteries play in the distribution of electrical energy is much the same as a water storage tank plays in water supply systems (Figs. 1 and 2). Without the tank the pumps have to supply a variable demand; their capacity must therefore be sufficient for the *maximum* demand. Moreover they must be operated 24 hours a day; the power consumption is much increased and the efficiency consequently reduced, to say nothing of the excessive mechanical strains imposed by sudden variations of the load. A water tank of sufficient capacity remedies all this; the capacity of

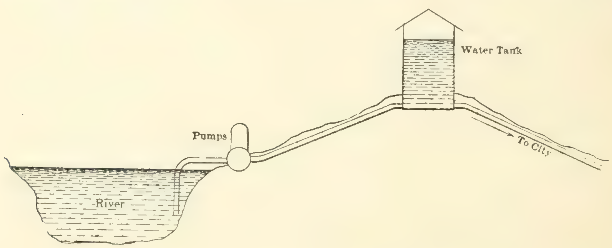


FIG. 1—A WATER-SUPPLY PLANT; BEING ANALOGOUS TO AN ELECTRIC PLANT
Pumps, like generators, supply the energy; a water tank takes the place of a storage battery and equalizes the load.

the pumps needs to be sufficient for the *average* demand only, and they may be operated at practically full load. When the demand is below the average, the excess of water pumped simply raises the level in the tank. When the demand is above the average, the tank supplies the necessary excess of water to the mains. In addition to this the tank allows a more constant pressure to be maintained in the mains even with variable flow.

2. *Regulation of Load and Voltage*—Similarly, in an electric

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*Chapter on Storage Batteries from the author's forthcoming book, "Experimental Electrical Engineering." Delivered in lecture form before The Electric Club, March, 25, 1907.

power house without storage batteries the generators have to supply the variable demand and are subjected to all the disadvantages resulting therefrom, viz: their capacity must be sufficient for the heaviest overloads which may occur; the machines must be operated 24 hours a day or at least as long as there is even the smallest demand for light and power; the engines are subjected to severe mechanical strains and are working under the most unfavorable conditions, as far as efficiency is concerned—namely at variable load.

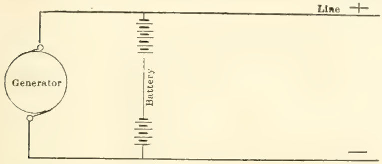


FIG. 2—A GENERATOR AND STORAGE BATTERY CONNECTED IN PARALLEL TO THE LINE

A battery so arranged is sometimes called a "floating battery."

When a storage battery is connected in parallel with the generators (Fig. 2) the latter need have a capacity sufficient only for the *average* daily load, and may be worked practically all the time at this load. When the load is below normal, the excess energy is sent into the batteries, charging them. At the hours of maximum demand (peaks of the load) the battery discharges into the line in parallel with the generators. During the hours of very small demand the engines may even be shut down, the battery alone supplying the current. The efficiency of the plant is thus increased, and a steadier pressure maintained with fluctuating loads.

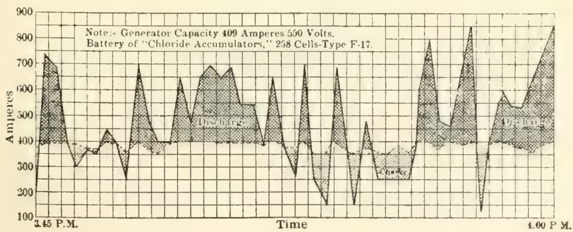


FIG. 3—EFFECT OF A BATTERY IN STEADYING GENERATOR LOAD

The peaked curve represents the total load; the dotted line shows the generator current which is practically constant.

Fig. 3 shows the effect of a storage battery in steadying the generator load; while the total load varies between 150 and 850 amperes, the generator load is kept at an average of between 350 and 400 amperes. Fig. 4 illustrates the influence of a storage battery

in maintaining a constant voltage. Without the battery the voltage fluctuates between 108 and 122 volts; the battery limits the fluctuations between 113 and 118 volts. Both Figs. 3 and 4 represent actual curves observed experimentally in certain power houses.

The limitations which at present prevent the universal use of storage batteries are: their comparatively high first cost and depreciation, additional complications resulting from extra apparatus needed for controlling and charging the batteries, and the amount of care required in their maintainance. There are many cases, however, especially in city electric railway work, where the advantages gained by the use of batteries by far outweigh the disadvantages; in such cases storage batteries are extensively used.

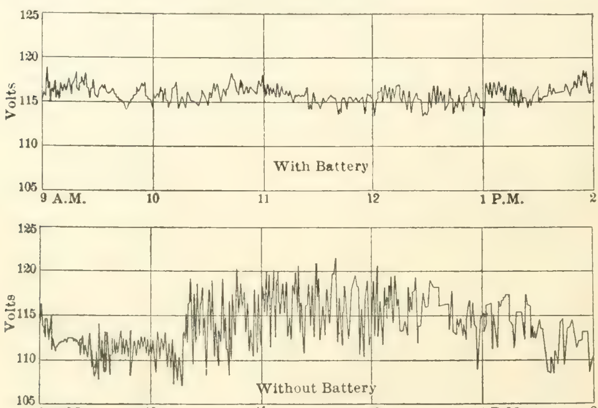


FIG. 4—EFFECT OF A BATTERY IN STEADYING THE LINE VOLTAGE

The lower curve gives voltage fluctuations when the generator is working alone; the upper curve corresponds to the case of a battery connected in parallel with the generator.

3. *Construction and Chemical Action of Storage Batteries*—An electric storage cell is a voltaic couple, in which plates of sponge lead ($Pb$) and peroxide of lead ($PbO_2$) are used as active materials (Fig. 5). These plates are immersed in dilute sulphuric acid ($H_2SO_4$) which acts as an electrolyte. When the battery discharges, both active materials are partially converted into lead sulphate ($PbSO_4$), and the acid becomes more dilute. On charging a reverse action takes place; the plates being again reduced to lead

peroxide (positive plate) and spongy lead (negative plate). The specific gravity of the electrolyte increases to its normal value, and the battery is again ready for discharge.

These chemical changes may be represented by a formula, thus:—

$$PbO_2 + Pb + 2H_2SO_4 \underset{\xrightarrow[\textit{discharge}]{}}{\overset{\xleftarrow{\textit{charge}}}{=}} 2PbSo_4 + 2H_2O.$$

In reality the chemical reactions are much more complicated and hardly known at present in all details. The above fundamental equation is, however, sufficient for a general understanding of the operation of storage batteries.

Impurities in lead and in the electrolyte produce local chemical

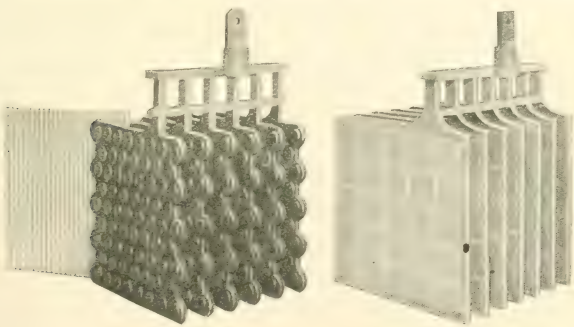

FIG. 5—STORAGE BATTERY PLATES

The negative plate to the right consists of a flat chamber made of two thin perforated lead sheets filled with active material. The positive plate to the left consists of a supporting grid with buttons rolled from lead ribbon inserted in it. A wooden separator is shown still further to the left.

action which may ruin the plates. It is important, therefore, to use pure materials. The manufacturers insist in particular that chemically pure sulphuric acid and distilled water be used.

There are two types of battery plates, called the Planté type and the Faure type, after their respective inventors. In the Planté plates the active materials, spongy lead and lead peroxide, are "formed" on the plates themselves by successive charges and discharges, or chemically.

In the Faure or "pasted" plates the active materials are applied mechanically to a supporting grid. This grid is of lead; it supports the active materials and conducts the current to the terminals. The pasted materials usually require some formation by electrical or chemical processes before they are brought to their final form.*

4. *Voltages on Charge and Discharge*—A storage cell has an e.m.f. of a little over two volts on open circuit. If allowed to be discharged indefinitely the voltage will at first remain practically constant at about two volts, then will gradually fall off, at first slowly then more and more rapidly down to zero (Fig. 6). The voltages given in the curve are to be measured while a normal discharge current is flowing through the cell. The voltage drop is due to the internal resistance of the cell and to some polarization on the surface of the plates.

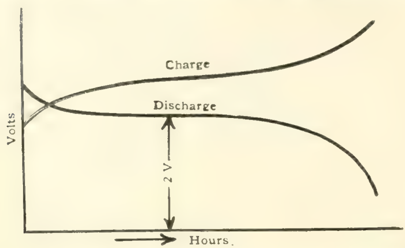

FIG. 6—CURVES OF CHARGE AND DISCHARGE VOLTAGES IN A STORAGE CELL

A complete discharge down to zero voltage would be impracticable, because for all ordinary purposes the terminal voltage of the battery must be constant within rather narrow limits. Moreover, such a complete discharge would ruin the battery. The reason for this is that lead sulphate, $PbSO_4$, which is formed during discharge is practically an insulator, and if too much of it is allowed to be formed on the plates, the reduction back to $Pb$ or $PbO_2$ is very difficult, if not impossible. Enough lead or lead peroxide must remain on the plates to keep down their resistance. Otherwise charging current cannot flow through the active material and effect a regeneration of the battery. In practice it is considered that the battery requires a new charge when the voltage has dropped to 1.75 volt. (or better 1.8 volt.) This voltage is measured with the battery supplying a current which corresponds to the eight-hour rate of discharge.

When the battery is being charged, the external voltage applied at its terminals must be high enough to overcome the counter-e.m.f.

*For details of construction of various types of plates and of the manufacturing processes the reader is referred to Lamar Lyndon's "Storage Battery Engineering," p. 103-155.

of the cell and to force the charging current through its ohmic resistance. At the beginning of a charge the charging voltage is a little above two volts per cell. As the battery becomes recuperated this voltage must be gradually increased, it being necessary to apply about two and six-tenths volts at the end of the charge in order to get full charging current through the cell. The end of the charge is also recognized by an excessive liberation of gases (boiling) due to a decomposition of water in the solution.

The best indication, however, of a complete charge is that the specific gravity of the acid reaches its maximum and remains constant. Referring to the fundamental chemical reaction, given in § 3, this means that all sulphate is liberated, and the plates consist of pure lead and lead peroxide.

5. *Capacity of Storage Batteries*—The capacity of a cell, or the amount of electricity that it can give on discharge is measured in ampere-hours; a cell which can supply 25 amperes for eight hours, before the lower limit of the e.m.f.—1.8 volts (or 1.75 volts for some makes)—is reached, is said to have a capacity of $25 \times 8 = 200$ ampere-hours. Experience shows that the capacity of a cell depends essentially on the rate of discharge. The more rapid the discharge the less is the capacity; thus the above cell if discharged at a rate of 100 amperes would be completely discharged in one hour instead of two hours. Therefore, *in speaking of the capacity of storage batteries it is always necessary to mention the number of hours in which the battery is supposed to be discharged.* It is customary to rate stationary batteries on the basis of an eight-hour discharge, and batteries used on electric automobiles on the basis of a four-hour discharge. Storage batteries used in electric railway substations for taking up fluctuations of the load are usually rated on the arbitrary basis of one-hour discharge.

If a battery is intended to be discharged within a shorter period of time than the normal period, its rated capacity must be reduced in a ratio usually given by the manufacturer. Roughly speaking, if the capacity is 100 percent at an eight-hour rate, it is about 93 percent at a six-hour rate, 75 percent at a three-hour rate and only 50 percent at a one-hour rate. (See table in § 7.)

One of the reasons for a decrease in capacity at higher rates of discharge is that the electrolyte cannot circulate as rapidly as required, thus diluting the acid in the pores of the plates, before fresh acid can take its place. Another reason is that a layer of lead sul-

phate is formed on the surface of the plates, preventing further action.

6. *Testing Storage Batteries*—The principal points to be investigated in the performance of a storage battery are:

(1) Behavior at discharge.
  (a) Variations of terminal voltage.
  (b) Variations of density of the electrolyte.
  (c) Influence of the rate of discharge on capacity.

(2) Behavior at charge.
  (a) Variations of terminal voltage.
  (b) Variations of density of the electrolyte.

(3) Electrical efficiency.

(4) Internal resistance.

(5) Weights and dimensions per ampere-hour output.

There are a few more practical tests, such as influence of temperature, loss of charge by local chemical action, durability in service, etc., which in spite of their importance cannot usually be performed in the short time allotted to students.

Connections convenient for the test of a storage cell are

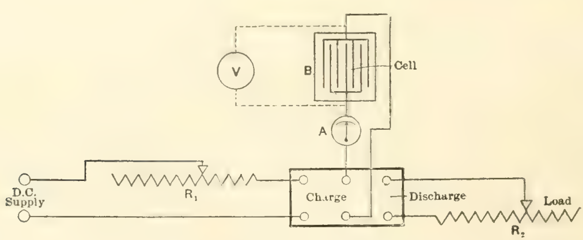


FIG. 7—CONNECTIONS FOR TESTING A CELL
The switch is thrown to the left for a charging and to the right for discharging.

shown in Fig. 7. By means of a double-pole double-throw switch the battery *B* can be connected either to the source of power (for c ge). to the resistance $R_2$ (for discharge). *A* is a two-way ..ding ammeter, *V*—a voltmeter connected across the battery terminals.

The tests above enumerated will now be described in detail.

7. *Charge and Discharge Characteristics*—The cell under test must be fully charged before beginning the experiment on discharge characteristics. The end of the charge is best recognized by the density of the acid, which reaches its maximum and remains constant. The voltage also reaches its maximum and remains constant. The absolute values of density and voltage are usually given by the manufacturer of the cell, and may vary within certain limits.

The time of charging should not be less than three hours if the battery has been completely discharged. At a higher rate of charging, the electrolyte warms up and the liberated gases cause it to boil; with the result that active material is washed out of the plates and the useful life of the battery is thereby reduced. Below this upper limit the amount of electrical energy necessary for charging is essentially independent of the charging rate.

It should be well noted that the acid ought to have the prescribed density when the battery is fully charged. The density may be corrected by the addition of distilled water. This should be done only when the battery is fully charged *and under no other circumstances.*

After the battery has been fully charged, the switch (Fig. 7) is thrown over to the discharge side. The current is adjusted to the desired value and maintained at this value until the end of the discharge. The curve of voltage on discharge has the general aspect shown in Fig. 6. It drops rapidly at the beginning and at the end of the discharge, and remains practically constant between. Therefore, readings should be taken every few minutes at the beginning and end of the run; a few check readings are sufficient for the rest of the time. Read volts, density of acid (on a hydrometer) and temperature; stir the liquid before reading the hydrometer, so as to measure the true average density.

The constant current of discharge multiplied by the number of hours of the test to the time when the battery is considered discharged gives the ampere-hour capacity of the cell. This capacity, multiplied by the *average* voltage during discharge, gives the watt-hour capacity. The test may be repeated with various rates of discharge, and the influence determined which the time of discharge has on the capacity of the battery.

The following table gives the voltages at which the discharge should be stopped (for "Chloride" batteries):

| Hours Discharge | Final Voltage | Relative Values of Current | Relative Capacity in Amp. hrs. |
|---|---|---|---|
| 8 | 1.75 | 1 | 8 (100%) |
| 3 | 1.70 | 2 | 6 (75%) |
| 1 | 1.60 | 4 | 4 (50%) |
| $\frac{1}{3}$ | 1.40 | 8 | $2\frac{2}{3}$ ($33\frac{1}{3}$%) |

In every case the voltage is to be measured with a discharge current flowing at the corresponding rate.

8. *Cadmium Tester*—In order to ascertain the state of charge on both plates a cadmium tester is sometimes used. It consists of a stick of pure cadmium placed in the acid of the cell under test. It is well to have the cadmium protected by a hard rubber tube with perforations for the circulation of the acid. At the end of the charge the voltmeter must show about 2.45 volts, between lead peroxide and cadmium, and about 0.10 volts between the lead plate and cadmium. This is a more or less positive indication of the end of the charge. The voltage between the two plates is equal to the sum of the two readings:—

$$2.45+0.10=2.55 \text{ volts.}$$

The same tester can be used to ascertain the end of discharge. In this case the voltages are + 1.95 and — 0.20 volts respectively, and the battery voltage is

$$1.95-0.20=1.75 \text{ volt.}$$

In case it is found that one of the plates is not fully charged, the charge must be continued until the cadmium tester shows the required voltage. Or, if it is feared that an excessive charge may damage the other plate, the plate which requires additional charging may be charged in a separate cell. Such a cadmium tester gives reliable indications in the hands of an experienced observer, especially when many tests are made on batteries of the same type. Otherwise it is safer to judge of the state of the charge from the acid density and the voltage.

9. *Internal Resistance*—The determination of the *true* ohmic resistance of storage batteries is rather difficult because this resistance is very small, is variable and is to some extent masked by the

effect of polarization. Moreover, it is not the true resistance, but rather the *virtual* resistance of the cell that is interesting to the user, this virtual or equivalent resistance representing the total drop of voltage in the battery, due to whatever causes. The simplest method to determine the resistance $R$ of a cell would be to observe the voltage $E_0$ on open circuit, and then immediately note the voltage $E$ with a certain charging current $I$ flowing through the battery. Then evidently

$$R = \frac{E - E_0}{I}.$$

A better method is to measure two terminal voltages $E_1$ and $E_2$ corresponding to two different values $I_1$ and $I_2$ of charging current. Then,—

$$E_1 - p - E_0 = RI_1;$$
$$E_2 - p - E_0 = RI_2;$$

where $p$ is the counter-e.m.f. of polarization. Eliminating $p$ and $E_0$ and solving for $R$ we obtain,—

$$R = \frac{E_1 - E_2}{I_1 - I_2}.$$

An objection to this method is that the e.m.f., $p$, of polarization is not quite constant with various rates of charge. Another objection is that the difference $[E_1 - E_2]$ is rather small and this impairs the accuracy of the result. It is advisable to perform a large number of tests with various values of $I_1$ and $I_2$ and to take an average of the calculated values of $R$. Experience shows that more consistent results are obtained on discharge than on charge. The same formula is used, as that given above.

Another way of measuring the resistance of a cell is the so-called "break" method which is considered by some to be more reliable. A certain value of discharge current through the cell is adjusted and when the conditions become steady, the circuit is suddenly opened. The pressure, as shown on the voltmeter, rises instantly a certain amount and then continues to rise *gradually* as the polarizing bubbles of gas disappear. It may be assumed with a considerable degree of accuracy that the first (instantaneous) rise in voltage corresponds entirely to the ohmic drop, since the bubbles of gas are evidently the same as a moment before when the circuit was closed. From this rise in voltage and the current formerly flowing through the battery, the internal resistance can be calculated. Suppose, for example, that the voltage rises from 1.8 to 1.9 volt

when the switch is opened, with 100 amperes flowing through the battery. The resistance of the cell is $0.1 \div 100 = 0.001$ ohm.

10. *Experiment A—Testing Storage Cells*—The experiment is performed as described in §§ 6 to 9. The readings during charge and discharge are taken at comparatively infrequent intervals; it is possible, therefore, to test simultaneously more than one cell. One voltmeter and one milli-voltmeter with several ammeter shunts are sufficient for all the cells. Some cells may be charging while others are discharging. Tests at low rates may be continued throughout several consecutive days by different observers, who may work out the results together.

At the end of the experiment measure all the dimensions of the cell and of its elements, so as to be able to make a drawing to scale. Determine the weight of the plates, of the electrolyte and of the complete cell. Do not keep negative plates out of the liquid longer than necessary; they may be damaged by the atmosphere.

The report should comprise:—

(a) Capacity of the cells tested, in ampere-hours and in watt-hours, at various rates of discharge.

(b) Corresponding efficiencies, both for ampere-hours and for watt-hours, which latter is always lower than the former, because the average voltage is lower at discharge than at charge.

(c) Curves of variation of voltage and acid density at charge and at discharge.

(d) Virtual and true resistance of the cell.

(e) Capacity in ampere-hours per pound of complete cell; also per pound of plates.

(f) Charge and discharge in amperes per square foot of plate surface.

(g) A complete drawing of the cell.

*(To be continued)*

# SALES CONTRACTS*

## CONTRACTS IN GENERAL

B. A. BRENNAN

Contract Manager, Westinghouse Machine Company

IT IS well known that those charged with the duty of making and approving contracts are oftentimes meagerly alive to the fundamental features of contractural obligations, and if one were to study the subject, observing the faulty character of most contracts and considering the tremendous volume of business which is transacted under such contracts with comparatively little complication and misunderstanding, it would, of necessity, make him an optimist. His recognition of the evidence that most business is conducted on faith, with an underlying spirit of confidence pervading most commercial transactions, would convince him that most people are honest, and demand merely that to which they are entitled. It will not be disputed, however, that contracts are necessary as a record of understanding, and they are necessary, too, as a precaution to both parties. On the first count, they should be specific in the expressed terms, and in the second instance, they should, by observing all necessities of the business, protect both parties from the risks, liabilities or penalties which, in spirit, they are not to assume, nor can they afford to assume, and which otherwise, either through ignorance of equity, or direct intent, would be forced upon them. It is not the salesman alone, nor the officer who passes upon the form, who requires to know how a contract should be drawn and its provisions interpreted. A contract once made, may require the participation of many in its execution, and every man connected with a business is obligated, both to himself, his employers and associates, to familiarize himself with the general legal regulations covering business intercourse or business agreements.

In the consideration of this subject, it must be remembered that statutory provisions exist in most states, and that the same differ widely in character with respect to the technical provisions of form and procedure.

Every one knows that a contract is an agreement, but how many of us realize that an agreement is not always a contract? It

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*A summary of certain parts of Brennan's Hand-book, prepared by the author especially for the *Journal*. This Hand-book is now in the course of publication.

might be a contract, but, to be so, it must possess certain elements which are required by law. An agreement is simply the meeting of minds; whereas, a contract is an agreement between parties, which, for a consideration from one to the other, creates an obligation on each to perform his respective covenants. Every agreement is not enforcible. To be enforcible, it must contain the legal elements known as *competent parties, mutual assent, lawful subject-matter,* and *sufficient consideration.* All of these are necessary to a perfect contract, and the absence of any one of them affects the contract. In some instances, depending upon the nature of it, the absence of any one of these elements makes the contract unenforcible; in others voidable, and in still others absolutely void.

There must be, at least, two parties to a contract, and they must be competent. By "competent" is meant natural persons or corporations with legal right of contracting. Natural persons, in this sense, are those of legal age, and those who are not incapacitated by physical or mental conditions which exclude consent, or by law or statute which prevents certain persons from entering into contracts or restricts their power to do so. The legal age of males is twenty-one years, and the same in most states for females, although in some states the legal age of females is eighteen years. Persons under age are termed minors. As a rule, contracts with minors are voidable, the idea of such law being to protect those under age against the consequences of their own indiscretion or against the imposition of others. Minors are liable, however, for all necessaries of life. Other persons not competent parties to valid contracts are:—convicts during the continuance of their conviction, insane persons, or those who can prove that they were *non compos mentis* at the time of contracting; persons intoxicated, or under the influence of drugs, so as to be deprived of consciousness of what they were doing at the time of contracting. Corporations usually have the same power of contracting as natural persons, but contracts made by them must be either expressly or impliedly authorized by their charter or act of incorporation.

Mutual assent is the meeting of minds. Obviously, there can be no contract if there is no agreement, and unless the parties have in mind the same understanding, with the common intention of binding themselves and each other by the arrangement, there can be no agreement. However clear the agreement may appear on its face, if it can be conclusively shown that it was not mutually understood, it cannot, in general be enforced. The parties must communicate

to each other their common intention, and no contract which the law will recognize and enforce exists until the respective parties have agreed upon the same thing and in the same sense.

Every contract must necessarily be the result of an offer on one side and its acceptance on the other. The acceptance must be in a simple and direct affirmative, and if the party receiving the proposal accepts it on any condition, or with any of its terms or provisions changed, unless the same be altogether immaterial, it amounts to another proposal by the other party, and there is no contract until the party making the proposal consents to the modification, either in writing or by overt acts amounting to the same thing. To be certain of proper mutual assent, every agreement should be written and signed by both parties and everything agreed upon should be written distinctly. Care should be used to say all that is meant and nothing else, for it is a rule at law that no oral testimony shall control a written contract unless its wording is so ambiguous as to practically demand definition of intention, or unless fraud can be proven. As a rule, any contract may be altered after execution, by consent of the parties, and any changes made at the time of or prior to the signing of the contract become elements in it. Any changes, however, after execution makes a new contract out of the original, and accordingly any guarantor, or third party to it, not assenting to the change is released from his obligation.

In the absence of fraud, a person is bound by his written agreement, notwithstanding he may have misapprehended the legal effect of it. Parties to contracts are assumed to know the liabilities imposed upon them by law. In order to charge one who can neither read or write, with liability under a contract, it must be shown that the contents of the paper were fairly read or explained to him. A party negligently signing a contract without reading it cannot avoid it by claiming afterwards that it contains provisions he did not understand or know of at the time of execution. Fraudulent representations made prior to the consummation of a contract, operating as an inducement thereto, and relied upon by the party to whom made, will defeat recovery by the party making them. Likewise a contract obtained under duress is void.

The subject-matter of a contract is the basis of the contract itself, and is descriptive or applicable to the promises of the parties, comprehending both the consideration to each and their respective obligations. Lawful subject-matter, as implied from its title, requires that the basis of the contract shall be of legal character, and that

the agreement itself shall otherwise conform to the legal requirements. The law refuses and forbids contracts involving agreements to perform an act forbidden by statute, or acts which in the law are penalized. Under this category would come agreements to pay usurious interest, contracts of wager, contracts for services of one who sets himself up as a physician who has no diploma, contracts made on Sunday, contracts to commit crime, civil wrong, or fraud on creditors. The law also forbids contracts opposed to public policy, as being injurious to the interests of the public. These are generally classed under agreements which tend to injure the public service, and of which graft is a striking example; agreements tending to obstruct the course of public justice, such as agreeing to suppress evidence at a trial; agreements tending to encourage litigation; agreements contrary to good morals, those restricting the freedom of trade, or those affecting the security of property and life.

It is difficult to clearly define Consideration as applied to contracts. Generally speaking, however, it consists of the reciprocal and mutual promises between the contracting parties. It might be called the benefits which each party receives, or the something to be performed or given in exchange by one party to the other for the inducement. The law says that consideration of some legal character is absolutely essential to a valid contract, and it further says that the consideration must be valuable and good, and must consist of some benefit, interest, right or profit to the parties, which denotes some substantial cause for the promise. For example, if A owes B $100, and B tells A he need not pay it, B can afterwards, nevertheless, repudiate his concession, on the score that there was no consideration for it.

Impossible conditions will void a contract, that is, where at the time the agreement is made it is known by the parties that a promise is physically impossible of performance. It must appear, however, that the promise cannot by any physical means be accomplished, and not that its fulfillment is deemed impossible because it is difficult and absurd.

In a sales contract the price is the consideration on one side, and the furnishing of the goods on the other. To constitute a sale, there must be something to sell. This does not mean that a concern could not sell or contract to deliver a turbine or generator not yet built, but that any hope or expectation of means, founded on a right in being, may be the subject of sale, because in such case there is a potential existence. But a mere possibility or contingency, not

founded upon a right or coupled with an interest, cannot be made the basis of a valid contract.

Price in a contract of sale is essential to its validity, and must be either determined or determinable. It need not necessarily be paid down, but there must be an agreement to pay. In the absence of a fixed price, the law would imply a promise to pay as much as the property was reasonably worth. If the contract be silent as to the time of payment, a cash sale will be presumed.

Every agreement must necessarily result from an offer or proposal on one side and an acceptance of it on the other. To illustrate: The sending of an order to a merchant or manufacturer is an offer to purchase, and the sending of the goods is the acceptance of the offer and creates the contract. The entering of a street car and riding in it amounts to an agreement by the railroad to carry the person on the usual route, at the usual fare, and an agreement by the passenger to pay the usual fare. A man, with full knowledge of another, does work for him, the latter knowing that he expects to be paid for it; the doing of the work is the proposal and the receiving of the work without dissent is the acceptance. If a man sends goods to another, and the other accepts the goods, or uses them, it implies a contract, and the user is liable for what the goods are worth.

In the preparation of a contract, it is important that it be grammatically written and construed according to the rules of grammar. This is not, however, an absolute rule at law, as it is not material in what part of the instrument any clause is written. It will be read as of any place and any context, so long as its certain and evident intent requires it. It is dangerous, however, to permit inaccuracy or confusion in the arrangement of clauses, because the true intent may thus be distorted and not admit of ready construction. There are many words and phrases which have one meaning in ordinary narration, but quite another when used as technical description, or words in relation to some special subject, and it must be supposed that the words as used are in the specific and technical sense applicable to the subject. In the construction of contracts, the main idea is to determine the intention of the parties, and it is a rule that the whole contract shall be considered in determining the meaning of any and all of its parts.

Contracts are often construed by the courts as including all matter which it is clear the parties intended, whether expressed or not, and to contain not only the expressed agreements but those implied

as well. That is to say, usages or customs of a country may affect the meaning of certain words. How plainly this would apply to engineering questions, where usages and practice may affect the meaning of certain words, and where incidents universally attaching to the subject matter must be presumed to have been in contemplation by the parties. It is settled law that every trade has its usages and that these usages are a part of every contract with reference to the subject matter.

In the interpretation of contracts of which a part is printed and part written, the printed parts are subordinated to that written, if they are in conflict and tend to different results. Mistakes in contracts can be rectified, if it can be proven that the parties intended to use one word, but used another by mere verbal error in copying or writing.

Contracts made on Sunday are governed by the laws of the particular state, but, generally, contracts executed on Sunday or legal holidays are void.

Contracts and bargains can be, and frequently are, concluded by written correspondence. An offer having been made through the mail, the proposing party may be regarded as tendering the post-office as his messenger, and when the other party accepts by post the agreement is complete and the contract made. The party to whom the proposal is sent must accept and mail his acceptance in due season, and if the one proposing desires to retract or modify it, he must communicate it to the party addressed before said party has mailed his acceptance, otherwise the proposer is bound. The proposer may, however, stipulate in the proposal that it shall not be considered as binding until the acceptance is actually received.

A salesman is usually authorized to do the specific thing of selling, being furnished with contract or proposal forms, which usually qualify that the proposal shall not be binding on his company until approved in writing by its executive officer at the home office. It is also customary in contracts of the kind to insert a clause stipulating that there are no promises, agreements, or understandings outside of the contract with reference to the subject matter, and that no agent or salesman has any authority to obligate his company by any terms, stipulations or conditions not expressed in the agreement. The importance and necessity of such provisions are obvious. Imagine, as is many times the case, a salesman at a place far remote from his home office, entering into an agreement, the performance

of which was predicated upon some local condition, and at the time, and during the negotiation, the salesman, in good faith and to the best of his judgment, makes certain statements as to the location of the machinery; that the place pointed out by the customer will permit of its ready installation without alterations to the building, etc., etc., that he considers the foundation suitable—or some other statement of the sort. We have seen many cases of the kind where the memorandum of agreement simply covered the apparatus to be furnished, but which did not contain clauses of the nature above mentioned, and it has followed that the customer, after receiving the machinery and attempting to install it, found that it was necessary to make certain alterations to the building, and afterwards made claim on the seller for the extra expense occasioned by the changes, and damages have been awarded on the score that, relying on representations made by the seller's agent, the customer purchased the apparatus with the understanding that it could be installed without such expense.

Frequently the salesman or engineer has occasion to go out and confer with customers relative to the details of contracts or the specifications. His company, wishing to have him received with standing, advises the customer that their Mr. so and so will call, etc., and instead of restricting his authority, rather emphasize it to some extent. How many of us appreciate that by simply doing this, the company may equip the salesman with authority to obligate it to an extent which may involve great expense. How many of us realize that on such occasion a mere word or admission, or assent, might bind the company beyond any degree of reason. The law says that unless the principal shall in some positive way notify the other party of the limit of the authority of his salesman or agent, he may be bound to the full extent of the salesman's acts; for a principal is responsible for the acts of his agents not only when he has actually given full authority to the agent to act for him, but when he has by words or acts, or both, caused or permitted the person with whom the agent deals to believe him clothed with this authority; and, if the agent transcends his actual authority but does not act beyond the natural and usual scope of business, the principal is bound, unless the party with whom the agent dealt knew the agent exceeded his authority. If a customer can prove that a salesman made certain promises or certain statements at the time the contract was entered into, thereby substantially interpreting the spirit of the contract, the law would interpret such verbal promises or statements to be collat-

eral to the agreement, and on which the customer could place valid claims.

The matter of terms of payment under a contract is one of its most important features, and we all know that the machinery manufacturer is oftentimes compelled to furnish apparatus for which he does not receive full payment on shipment. The general rule on small product is about one-half of the purchase price on shipment; the remainder thirty days after shipment; although, in some instances, where the customer is not strong, financially, payment before shipment is often exacted. On larger product, where the building of the apparatus requires any length of time, during which period a large amount of money is necessarily tied up in raw material, a portion of the purchase price is usually made payable as the work progresses in the shop; another payment when the apparatus is substantially completed in the shop; and the third payment on shipment, or delivery, with the balance within a reasonable time thereafter.

The all important consideration in contract terms, is that they be specific. A contract is always faulty, the terms of which permit of diverse interpretations, and, oftentimes, extended terms are less objectionable, if they be clear and unquestionable, than short terms with an uncertain basis of maturity. The greatest conceivable defect in expressing terms of payment, would be to have them dependable upon the customer's temperament, mood, or, perhaps, caprice. The employment, therefore, of such terms as "Satisfactory operation," "Erected complete," "Tests to verify guarantee," "When in successful operation thirty days," or, in fact, any contingency which would permit the customer, himself, to define the terms contrary to the seller's intention, or the spirit of the contract, is dangerous and costly, and should not be used.

# RAILWAY SIGNALING—IV (Cont.)

## THE ELECTRIC TRAIN STAFF SYSTEM

T. H. PATENALL

### ABSOLUTE STAFFS AND STAFF INSTRUMENTS

In the operation of the electric train staff the track to be protected is divided into blocks or sections of such length as to best accommodate local and traffic conditions. These blocks usually terminate at existing stations or telegraph offices, though occasionally, as in the telegraph block system, additional block stations have to be installed when the distance betwen any two existing stations is too great for the expeditious handling of traffic.

Each section is controlled by two instruments of the type shown in Fig. 1, one at each end of the section, which for convenience in this description are referred to as "*X*" and "*Y*." Each instrument is equipped with a sufficient number of staffs (varying from 10 to 35 per section) to take care of the traffic conditions. No train is permited to proceed between *X* and *Y* in either direction unless the conductor or engineer has in his possession one of these staffs which is in effect a metal train order. The instruments at *X* and *Y* are electrically connected and synchronized so that the withdrawal of a staff from either can only be effected by the joint action of the operators at *X* and *Y*, and but one staff can be out of both instruments at any one time.

To move a train from *X* to *Y* the manipulation of the instruments is as follows: The operator at *X* presses bell key *A*, Figs. 1 and 3 the number of times prescribed in the bell code, which rings bell L, Figs. 2-3 at *Y* through circuit *1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18*. The operator at *Y* first acknowledges receipt on his bell key by ringing bell *L* (Figs. 2-3) at *X* (through circuit *19, 20, 21, 8, 7, 6, 5, 4, 22, 23, 24, 25, 17, 16, 15, 14, 13, 26*,) and then holds it closed, thereby deflecting the "current indicating needle" *F* at *X* (Figs. 1-3) to the right. This informs *X* that *Y* has furnished *X* current and he proceeds to remove the staff by turning the preliminary handle *B* Fig. 1 to the right as far as it will go, which raises the armature *J* Fig. 2 up to the magnets K (Fig 2) transferring the current from the bell L to the coil *K88* (Fig. 3) through the circuit *19, 20, 21, 8, 7, 6, 5, 4, 22, 23, 27, 28, 25, 17, 16, 15, 14, 13, 26*, and at the same time closing the circuit on coil *K 360* (Fig. 3)

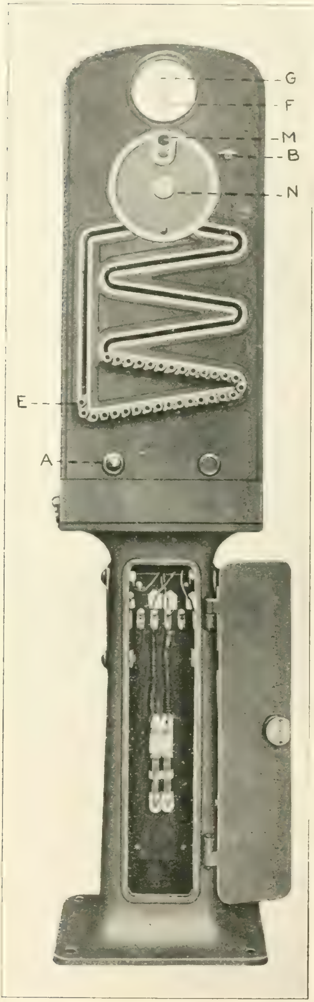


FIG. 1—STAFF INSTRUMENT SHOWING TRAIN STAFFS, REVOLVING PLATE, INDICATING DIAL, SIGNALING BUTTON, ETC.

through the circuit *1, 2, 29, 30, 28, 25, 18,* after which the preliminary spindle handle *B* (Fig. 1) is permitted to automatically return to its normal position. This unlocks the revolving drum *C* (Figs. 2 and 4) and indicates the fact by displaying a white instead of a red disc in the indicator at *F* (Fig. 1). The operator now moves the end staff *E* (Fig. 1) up the vertical slot into engagement with the drum *C,* (Figs. 2 and 4) the outer guard *N* (Fig. 1) having first been turned to the right position; revolves the latter through half a turn, using the staff as a handle, and finally withdraws the staff through the opening at M (Fig. 1). In making the half turn, the drum *C* has reversed the polarity of the operating current, thereby throwing the instruments at *X* and *Y* out of synchronism with each other, and moving the "staff indicating needle" *G* at *X* (Fig. 4) from "Staff In" to "Staff Out." Immediately on withdrawing the staff the operator at *X* once more presses his bell key *A,* which indicates to the operator at *Y* by moving his needle from "Staff In" to "Staff Out" that the operation is completed. A side view of a staff instrument with the outer case removed is shown in Fig. 5.

The staff withdrawn is now delivered to the train by hand if

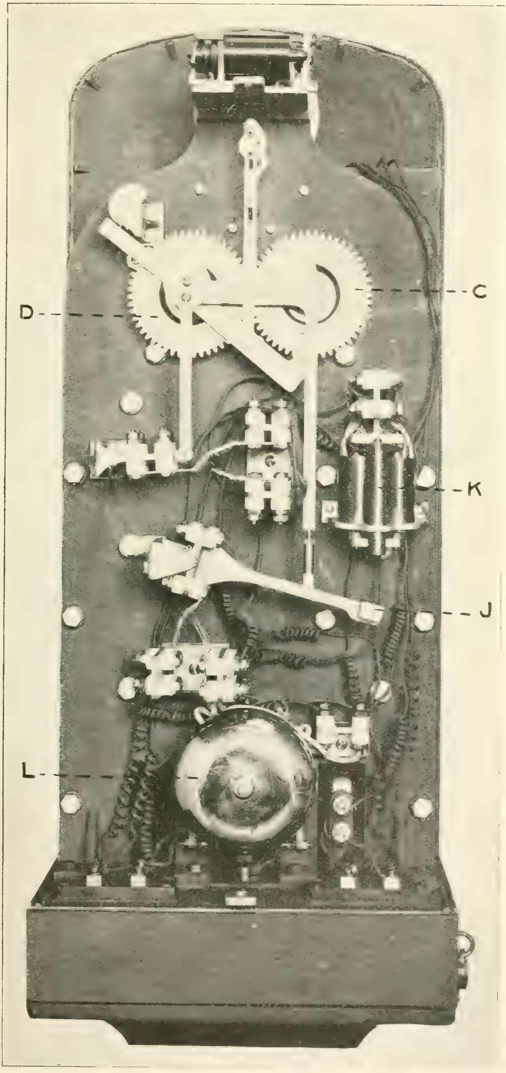


FIG. 2—BACK VIEW OF STAFF INSTRUMENT SHOWING MECHANISM

the train is at rest or passing at a speed less than 25 miles per hour. For higher speeds the staff is placed in a special holder and delivered by methods similar to those followed in the railway mail service, the engine being fitted with a catcher and deliverer. A glance at the accompanying cuts (Figs. 6 and 7) will make this clear. As mentioned before, in taking out a staff, the polarity of the operating current is reversed. This prevents a second staff from being taken out of either instrument, as may be noted from the following.

The polarity of the local current flowing through magnet *K 360* (Fig. 3) is never changed, the polarity of the current flowing

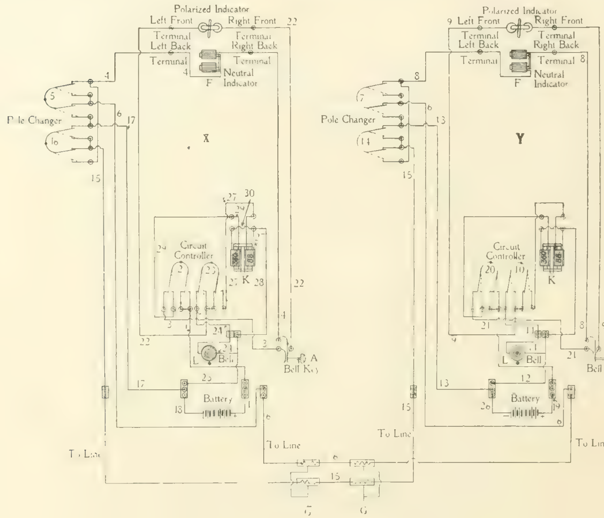


FIG. 3—DIAGRAM OF CONNECTIONS FOR INTERLOCKING, SIGNALING, AND INDICATING CIRCUITS FOR ONE BLOCK SECTION

through *K 88* (Fig. 3) is changed each time a staff is put in or taken out of either instrument. This puts the instruments either in or out of synchrony. The magnet *K* (Fig. 3) is formed of two separate coils, one energized by the local and one by the line battery. The construction of this magnet is such that when the currents in both coils run in the same direction, the lines of force flow around the cores and connecting straps, thus forming no point of attraction for the armature. When the current is reversed in one coil, however,

the lines of force oppose each other and the armature being brought to the point of attraction is held there. With the staff out, the circuits are as follows:—starting from the + side of battery at Y, (Fig. 3), through *19, 20, 21,* Bell Key A closed, *8, 7, 6, 5, 17, 25, 24, 23, 22, 4, 16, 15, 14, 13, 26,* to—side of battery at *Y*. If an attempt be made to release a staff by turning the preliminary handle, the operating current would be transferred from the bell *L* to coil *K 88* (Fig. 3) through *19, 20, 21,* bell key *A* closed (Fig. 3), *8, 7, 6, 5, 17, 25, 28, 27, 23, 22, 4, 16, 15, 14, 13, 26* to—side of battery at *Y*. By comparing this circuit with the one described for releasing a staff, it will be seen that in the former the currents flowing through coils *K 360* and *88* (Fig. 3) oppose each other and in the latter they do not, which prevents the releasing of a staff.

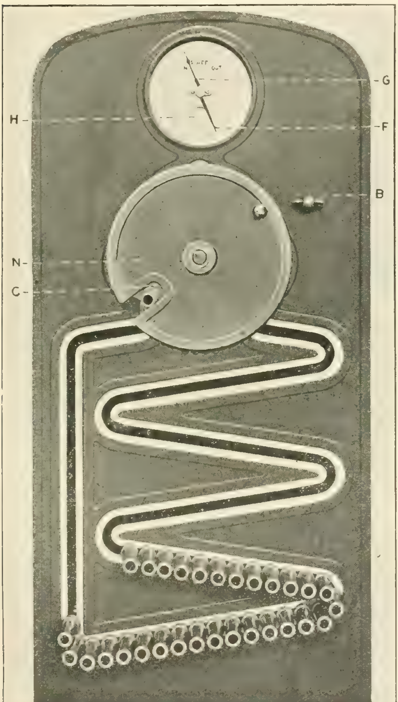


FIG. 4—FRONT VIEW OF STAFF INSTRUMENT WITH STAFF INSERTED IN DRUM AND OUTER GUARD IN POSITION

On arrival of the train at *Y* the staff is delivered either by hand or deliverer to the operator, who having seen that the train is complete by observing the rear end markers, places the staff in the opening *M* (Fig. 1) of his instrument, having first turned the outer guard *N* (Fig. 1) to place, moves the staff into engagement with the drum, *D*, (Fig. 2), revolves it through one-half turn, using

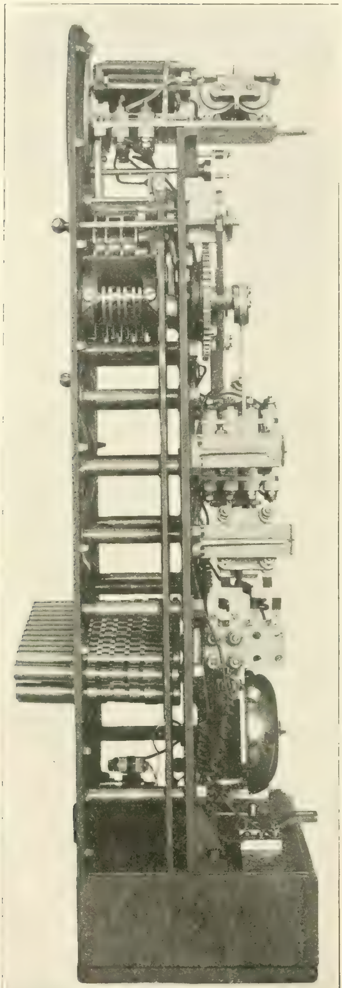

FIG. 5—SIDE VIEW OF STAFF INSTRUMENT SHOWING MECHANISM

the staff as a handle and allows it to roll down the spiral. He then presses his bell key the prescribed number of times, thus notifying *X* that the train is out of the section, which operation also moves the "staff indicating needle" at *X* from "Staff Out" to "Staff In." The operator at *X* presses his bell key in acknowledgment and by so doing moves the "staff indicating needle" at *Y* from "Staff Out" to "Staff In" (Fig. 8). The machines are now synchronized and another staff can be obtained from either in the manner above outlined.

The staff being put in the instrument at *Y*, the circuits are as follows: From + side of battery at Y through *19, 20, 21*, Bell key *A* closed at *Y* through *8, 14, 15, 16, 4, 22, 23, 24, 25, 17, 5, 6, 7, 13, 26*, to— side of battery at *Y*. Should a release be required, the preliminary spindle at *X* would be turned and current transferred from the bell to magnet *K 88* (Fig. 3), through the following circuit; from+side of battery at *Y* through *19, 20, 21*, Bell key closed at *Y*, through *8, 14, 15, 16, 4, 22, 23, 27, 28, 25, 17, 5, 6, 7,*

*13, 26,* to -- side of battery at *Y*. It will be seen that the current flowing through magnets *K 360* and *88* are again opposing each other, consequently, a staff can be released.

While it takes some little time to describe the method of operating the staff instruments, yet as a matter of fact, the removal of a staff actually takes less than five seconds and the operation of putting one in an instrument less than two seconds under ordinary conditions.

The same methods are followed at each succeeding staff station,

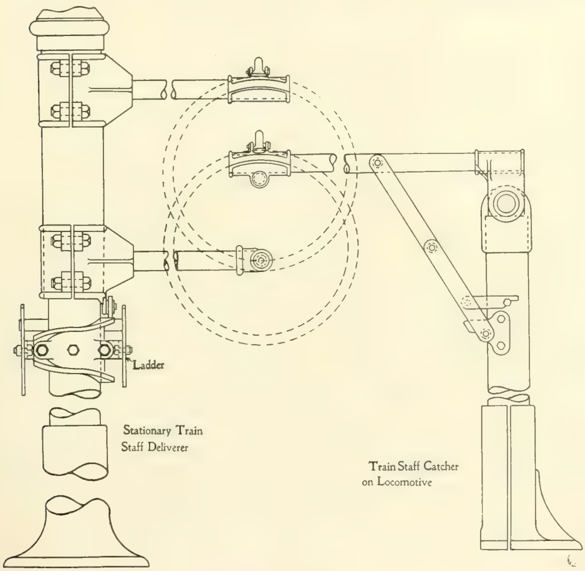


FIG. 6—APPARATUS FOR AUTOMATICALLY CATCHING AND DELIVERING TRAIN STAFFS SIMULTANEOUSLY AT HIGH SPEED

but no two adjacent sections use the same design of staff; that is to say, the staffs used between *X* and *Y* will not fit the instruments controlling the section between *Y* and *Z*. Usually four different designs of staffs are employed in actual practice to avoid any possibility of their being improperly used.

PERMISSIVE FEATURE

While the absolute system, where but one train is allowed in any

section, is the ideal arrangement, yet cases occur where it is desirable to allow several trains to follow each other into the block at short intervals. This is known as the permissive system, and consists of an attachment (Fig. 9) to the absolute machine at each end of the section with *one* permissive staff. An absolute staff is always locked in a permissive attachment when it does *not* contain the permissive staff.

To operate this feature an absolute staff is withdrawn from the instrument at *X* in the usual manner and used as a key to unlock the attachment or base (Fig. 9) containing the permissive staff (Figs.

FIG. 7—TRAIN STAFF CATCHER MOUNTED ON LOCOMOTIVE TENDER

As used on the Cincinnati, New Orleans & Texas Railway on their fast express trains where the staff has to be caught at speeds frequently exceeding sixty miles an hour.

10 and 11) which is then taken out. The opening of the base and the removal of the permissive staff locks the absolute staff in the permissive attachment, there to remain until the permissive staff is replaced at either *X* or *Y*. The permissive attachment with outer case removed is shown in Fig. 13. The permissive staff consists of a steel rod and 11 removable rings (Fig. 12) any one of which authorizes a train to pass through the

section to *Y*. If less than 12 trains are to follow each other, the last one takes *all the remaining rings and the steel rod.* When all the rings and the rod are received at *Y*, the operator reassembles them into the complete permissive staff (Fig. 11) which he then places in the permissive attachment or base (Fig. 10) and locks it therein by the absolute staff already in the lock of this attachment. By so doing he releases the absolute staff which he restores to the absolute instrument in the regular manner. The machines are now synchronized and a movement can be made with the absolute staff in either direction and from *Y* to *X* with the permissive.

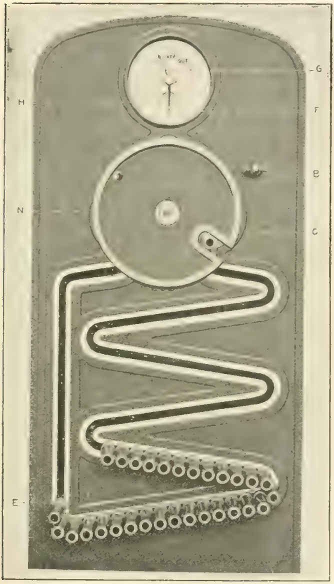

FIG. 8—FRONT VIEW OF STAFF INSTRUMENT WITH OUTER GUARD IN POSITION TO ALLOW A STAFF TO BE RELEASED AND ROLL DOWN THE ZIG-ZAG SLOT

If it is again found necessary to move several trains from *X* to *Y* under the permissive system, the permissive staff must be obtained by *Y* as before described and forwarded to *X* as a whole by the first train moving in that direction. When a train receives the entire permissive staff it confers the same rights as does an absolute staff.

CONTROL OF SIGNALS

In its capacity as a key the absolute staff has a number of uses in addition to that already described. Where signals are used to indicate to an approaching train whether or not it will receive a staff, an instrument known as the staff lever lock (Fig. 14) is attached to each lever operating such signals. To clear a signal the staff after being withdrawn is first used to unlock the lever lock (Fig. 14). The signal is then cleared and the staff removed from the lock and delivered to the train.

To insure the signal being placed at danger behind a train the

act of unlocking the signal lever opens the staff circuit, and no communication can be made between the two staff stations until the signal is at danger, and the lever locked in that position. This does not indicate, however, that the operator will have the staff ready for delivery by hand, or in the mechanical deliverer. To cover this point an electric slot is attached to the signal governing train movements into the staff section, which slot is controlled by the staff and lever lock and the mechanical deliverer, so that before the signal can be cleared the staff must be released, used to unlock the signal lever and put in the staff deliverer, which closes the circuit on the electric slot. The signal can then be cleared. With this arrangement, therefore, a clear signal can not be given until the staff is actually in the deliverer.

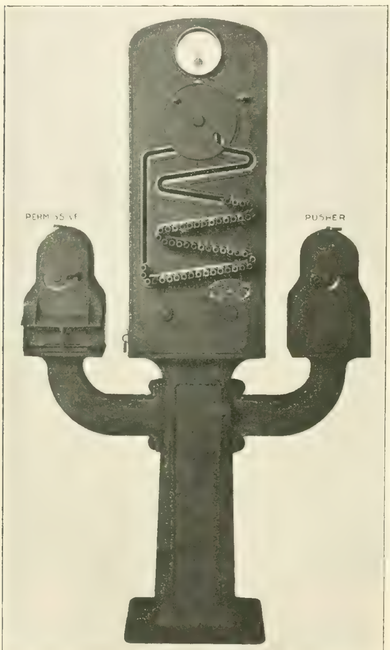


FIG. 9—FRONT VIEW OF STAFF INSTRUMENT WITH PERMISSIVE AND PUSHER ATTACHMENTS

When the train picks up the staff, the circuit on the slot is opened, automatically setting the signal to danger, which can not again be cleared until the operation described above is repeated.

SWITCH LOCKING

The staff is also used as a key to unlock siding switches which may occur between staff stations, the switch locks being so designed that the staff cannot be removed from the lock until the switch is set and locked for the main line, thus providing absolute protection against misplaced switches.

SIDING AND JUNCTION INSTRUMENTS

In some sections there is a siding of sufficient length to hold a train, but traffic would not warrant placing a staff at this point. That the usefulness of this long siding may not be lost, a special instrument is placed at the siding which enables it to be used for meeting or passing trains.

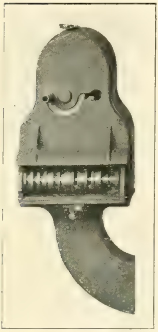

FIG. 10 — PERMISSIVE ATTACHMENT WITH STAFF RELEASED AND DOOR OPEN

FIG. 11—PERMISSIVE STAFF ASSEMBLED

The operation is as follows: A train arriving at the staff station *X* has not time to proceed to Y, but can proceed as far as the siding. The operator at *X* gives the train a staff with instructions to proceed to the siding. Unlocking the switch with the staff, the train takes the siding, closes and locks the switch, places the staff in the siding instrument, and turns the drum to the right. The staff is now locked in the instrument, and the staff instruments at *X* and *Y* are synchronized, and the fact indicated to both operators so that trains may be sent through the section in either direction.

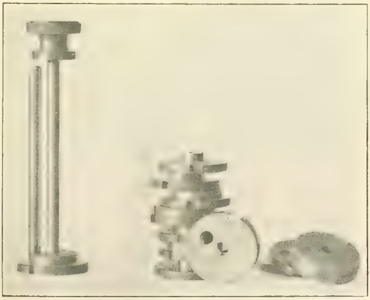

FIG. 12—PARTS OF PERMISSIVE STAFF

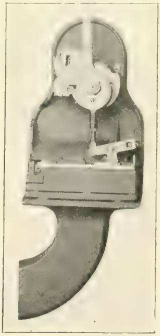

FIG. 13 — BACK VIEW OF PERMISSIVE ATTACHMENT SHOWING MECHANISM

When all trains having precedence over the one in the siding have passed through the section, and the staffs have been replaced in the instruments; *X* and *Y*

acting in conjunction can release the staff at the siding, which on being removed changes the circuits so that no staff can be released either at $X$ or $Y$. The train on siding then unlocks the switch with the staff and proceeds to $Y$ or back to $X$.

A junction or diverging line may be situated between two points most suitable for staff stations; but on account of the small amount of traffic over the diverging line it would not be desirable to

FIG. 14—VIEW OF STAFF LEVER LOCK WITH CASE REMOVED

make it a staff station. Such a point can be controlled in a similar manner.

PUSHER ENGINE ATTACHMENT

Another adjunct to the staff system is known as the pusher engine attachment and staff (Fig. 9) which is used on heavy grades where pusher engines are required, and is intended to both obviate the necessity of the pusher engine proceeding through the entire staff section, and to better equalize the traffic. It can readily be seen from the foregoing description of the staff system that under ordinary rules every train having a pusher engine attached would receive

one staff to proceed up grade as from *X* to *Y*. On arrival at *Y* the pusher engine would necessarily have to receive a staff to return to *X*. Supposing the traffic up and down grade to be equal and that each train going up grade requires a pusher, it is apparent that twice as many staffs would go down hill as came up, resulting eventually in all the staffs arriving at the foot of the grade, *X*, from which they could only be returned to *Y* by some special person authorized to unlock the instruments and remove the staffs by hand. Furthermore, the summit of the grade may be half-way between *X* and *Y*, but under the rules a pusher could not cut off at the summit and return to *Y*, but must continue on to *X* and receive a staff to return.

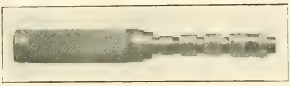

FIG. 15—PUSHER STAFF

To overcome these two objections the pusher attachment is employed. It consists (like the permissive attachment) of a separate device which may be attached to any absolute instrument (Fig. 9) and contains a staff of special design (Fig. 15) which can only be released by a regular staff, though, unlike the permissive staff, it can be out of its receptacle at the same time as the regular staff, but when so removed it opens the controlling circuits of the system, preventing any other movement being made until it has been returned and locked in the pusher attachment. Fig. 16 is a rear view of a pusher atachment showing the mechanism.

FIG. 16 — BACK VIEW OF PUSHER ATTACHMENT SHOWING MECHANISM

The operation is as follows: A train with a pusher wishes to proceed from *X* to *Y*. *Y* releases a staff at *X*, and *X* uses this staff to release the pusher staff. *X* then hands the regular staff to the train and the pusher staff to the pusher engineer. The train passes through the section and delivers the regular staff at *Y*. This is placed in the instrument there, the pusher engine retaining the pusher staff and returning to *X*. Until this latter staff is put into the pusher attachment at *X* and locked, the staff circuits are not re-established and no other staff can be released.

# RELATIVE ADVANTAGES OF ONE-PHASE AND THREE-PHASE TRANSFORMERS*

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IN considering the relative advantages of three-phase and one-phase transformers it will be assumed at the outset that the three-phase transformer is to be compared with a group of three one-phase transformers whose aggregate output is the same as that of one three-phase transformer; for it will be admitted at once that a comparison between one one-phase transformer and one three-phase transformer of the same output would be all in favor of the one-phase transformer. On this assumption, the advantages of the three-phase transformer over the one-phase group are as follows:—

1—Lower cost.

2—Higher efficiency.

3—Less floor space and less weight.

4—Simplification in outside wiring.

5—Reduced transportation charges and reduced cost of installation.

The disadvantages are:—

1—Greater cost of spare units.

2—Greater derangement of service in the event of breakdown.

3—Greater cost of repair.

4—Reduced capacity obtainable in self-cooling units.

5—Greater difficulties in bringing out taps for a large number of voltages.

The various advantages and disadvantages enumerated above will be considered in sequence.

ADVANTAGES

*Lower Cost*—A three-phase transformer should always be cheaper to manufacture than three one-phase transformers of the same total output; for by combining one-phase units into a three-phase unit, there results a considerable saving in active material due to the magnetic phase relations. Also there is only one containing

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*From the "Proceedings of the American Institute of Electrical Engineers" for April, 1907, by permission.

case, one set of end-frames, one cooling system, etc., to be provided for the three-phase unit.

The labor is also less, not only on account of there being less active material to handle in one case, one set of end-frames, etc., but because the unit as a whole is larger, and there is always less labor cost in manufacturing one large unit than there is in manufacturing several smaller units for the same total output.

*Higher Efficiency*—Since there is less active material in the three-phase transformer than in the one-phase group, the loss at the same densities will be less, and therefore the efficiencies higher, consequently the total radiating surface required may be less.

*Less Floor Space and Less Weight*—This follows from a consideration of the two preceding paragraphs.

*Simplification in Outside Wiring*—The star or delta connections of a three-phase transformer are simply and easily made inside the case, for as a rule only three high-tension and three low-tension leads are brought out; whereas with three one-phase transformers at least six high-tension and six low-tension leads are brought out and the transformers interconnected by suitable wiring.

*Reduced Transportation Charges and Reduced Cost of Installation*—The lighter weight and less bulk of the three-phase transformer will, in general, result in reduced transportation charges especially where shipment is made by water. This advantage is open to question, however, when there are long wagon hauls over mountain roads, with poor facilities for handling heavy machinery. In this case it may be cheaper to transport a greater weight and bulk in small units; but in general the transportation charges should be considerably in favor of the three-phase transformer.

It should also be noted that in many foreign countries duties are charged according to the weight of material, but whether duties are charged according to weight or price, the advantages are with the three-phase transformer.

In general, it will be cheaper to install one large unit than three small ones. This is particularly true where the transformer must be dried out on site by heating or by vacuum process.

### DISADVANTAGES

*Greater Cost of Spare Unit*—It is obvious that any three-phase unit having three times the capacity of a one-phase unit will cost considerably more. This may be of some importance where there is but one three-phase unit, but it will be found that in many cases

the cost of two three-phase transformers with a total capacity of 200 percent will be but little more than that of four one-phase transformers having a total output of 133 percent. Where there are several similar three-phase units it will be found that the reduced first cost of adopting three-phase units will more than pay the difference in cost between the three-phase and the one-phase spare unit. In addition, there is the advantage that the three-phase spare unit will have three times the capacity of the one-phase spare unit.

It should be noted, however, that with a three-phase or one-phase core-type transformer, there is much less need of carrying a complete spare unit than with the shell-type one-phase or three-phase transformer. This is on account of the very simple construction of the core-type transformer, and the ease with which it may be repaired. The top-yoke is built up in one solid piece and bolted down with butt joints to the three vertical cores. Thus it is necessary in case of repairs to loosen only a few nuts, remove the top yoke, slide off the damaged coils, and replace them with new ones; bolt down the yoke and replace the transformer in position. Should the lamination be welded together, it might be necessary to do considerable filing; but in general there is less chance of burning the laminations than with the shell type of construction. With a supply of spare coils, any ordinary burn-out should be repaired in a very few hours. On the Continent it is quite customary to use core-type three-phase transformers with only coils as spares, even for very important work; for it has been found in actual practice that repairs can be made in but litle more time than is required to replace one transformer by another.

With the present standard shell-type of construction, a much longer time is required for repairs on account of the fact that the laminations must be removed and replaced a few at a time. The repair of a three-phase shell-type transformer is so serious an undertaking that it would probably seldom be attempted on site, but would be returned to the manufacturer.

*Greater Derangement of Service in the Event of Breakdown*—When three one-phase transformers are connected in delta on both high and low-tension windings, one of the three may fail and be cut out, and the remaining ones will continue to carry about two-thirds the total load without overheating. With the star connection on either winding, this cannot be done. A three-phase core-type transformer cannot be operated with a short-circuit on any phase

The three-phase shell-type transformer may be operated, however, with a short-circuit on one phase provided both windings are in delta; but while this may be used as a temporary expedient for carrying partial loads, the whole transformer must be removed eventually for repairs.

In any event, whether core or shell-type transformers are used, there will probably be a somewhat greater delay in substituting a three-phase spare unit than in substituting a one-phase spare unit.

*Greater Cost of Repair*—With three one-phase units it is probable that in the event of breakdown in one, it will be cut out before the others are damaged. With a three-phase unit, where the phases are so near together, there is the possibility that a breakdown in one-phase may damage one or both of the others. In such event, there are two or three phases instead of one to repair; but in any event the repair of a three-phase transformer will be in general more expensive than a one-phase transformer of the same type.

*Reduced Capacity Obtainable in Self-Cooling Three-Phase Units*—In some cases it is highly desirable to use only self-cooling transformers. 1 500 kw is approximately the maximum size of three-phase transformer that with present methods of construction can be made self-cooling. A group of three one-phase self-cooling transformers can be built with an output of two or three times this amount. Thus, if an output greater than 1 500 kw is required, it will be necessary to use two three-phase transformers, a more expensive arrangement than three single-phase transformers. It is very seldom, however, that an out-put greater than 1 500 kw is required from a self-cooling transformer. When artificial cooling is permissible, the three-phase transformer may be built for any desired capacity.

*Greater Difficulties in Bringing out Taps for a Large Number of Voltages*—The increased difficulty in arranging the three-phase transformer for a large number of different voltages might in some cases prevent its use, but such cases will be of very rare occurrence, and need scarcely be considered.

To sum up, it may be said that the three-phase transformer has certain real and positive advantages over the one-phase type, while its disadvantages are chiefly those which result in the event of breakdown—an abnormal condition which occurs at rarer and rarer intervals as the art of transformer design and manufacture improves. It is the writer's belief that, as on the Continent, the three-phase transformer has already superseded the one-phase in most cases, so in America and Great Britain the use of the three-phase transformer

will show a very rapid increase within the next few years.

It is also the writer's opinion that a three-phase core-type transformer having as good or better performance than the shell type can be built for less money. This, together with the fact that the core type can be repaired so readily, makes it more desirable than the shell type.

In the above discussion, the three-phase transformer has been compared with three one-phase transformers, but it is possible to use two one-phase transformers with the V or T connection for three-phase working; and by placing the two in the same case, a considerable saving in cost over three separate transformers may be effected. On account of the phase relations of the currents, however, the capacity of each transformer must be 15 percent greater than half the capacity of the three-phase transformer, with a corresponding increase in cost and losses.

There is another serious objection to this arrangement, for on account of the out-of-phase relation of voltage and current the voltage across the three phases will not remain in balance as the load comes on.

It is also open to very serious doubt whether this transformer can be built as cheaply as can the three-phase core type. The writer does not believe that this type will ever come into very general use.

# ADVANTAGES OF THE ELECTRIC DRIVE

## IN ITS APPLICATION TO RAILWAY REPAIR SHOPS*

J. HENRY KLINCK

IN attempting to provide additional facilities for handling the increased work thrown on railroad repair shops by reason of increased demands made upon the rolling equipment, the limitations of a plant driven by steam engines belted to line shafting have come to be fully realized.

In such a plant it is necessary that the tools be placed rather in accordance with the line shafting than with the individual requirements of the work in hand. A line shaft is capable of transmitting only a given amount of power, and when this limit is reached, expansion must be stopped as far as any particular shaft is concerned. It is then necessary either,—to remove the shaft and substitute another of a larger size, increase the speed of the shaft, or install additional shafting, all of which methods are expensive and objectionable, and interfere seriously with the performance of the regular shop work. The many belts and countershafts necessary with this type of drive interfere with the placing of the tools, the lighting of the shop and the movement of the material through the shop. They require constant care and attention, and the amount of power wasted in them is an appreciable item. This fact has been fully recognized by the operating men of manufacturing plants for a long time.

In a comparatively recent instance a plant, which required on an average 300 horse power for its operation when belt driven, was converted to electric drive and the average load after this change was approximately 150 horse power. In a railroad shop, the importance of these losses is relatively greater for the reason that so much work is done overtime. At these times the power utilized is almost infinitesimal when compared with that wasted, as but few tools are in operation at once. The transmission loss, however, remains practically constant at all times. It is no unusual sight to see in an engine-driven railroad shop on a holiday, or after regular working hours, an engine capable of indicating, say, 200 horse power,

*Reviced for the *Journal* by the author from a paper read before the Southern & Southwestern Railway Club.

operating machinery requiring the merest fraction of its possible output.

In the layout of an entirely new shop equipment, the limitations of the engine-driven plant are even more apparent. With this type of installation, driven from a central power plant, it becomes necessary that the buildings making the heaviest demands on the power plant be located adjacent to it. This renders the arrangement anything but flexible, and compels much waste of useful time in the unavoidable transfer and re-transfer of material, which retraces its path many times in going through the plant, as a whole, but once. This disadvantage can be offset to a certain extent if the installation of individual engines in the various shops is considered advisable, but in this case the engines have either to be supplied from a central boiler plant by means of a network of steam pipes, or individual boiler plants have to be installed in connection with each engine. The only department in connection with which the separate engine plant works out at all economically is the planing mill, which frequently furnishes more than enough refuse to supply the fuel necessary for its operation. The maintenance charges and transmission losses with steam-piping greatly exceed the transmission losses incurred in electrical transmission.

Although the capacity of many shops previously in operation has been increased it has been found that even when it has been possible to increase the number of tools operated from the original engine-driven installation, it has hardly been possible to increase the output in engines or cars, in a given time, for the reason that the size and capacity of the engines, or cars, having increased, the sizes of the various parts of which they are composed has also increased, and each individual part of the latest type of engines, or cars, requires more work than those of earlier types. As a net result it has been the experience of shop men in general that the increase in the capacity of modern tools has just about increased in proportion with the additional work necessary to be done upon each individual part of modern equipment or cars. It is in this connection that the question of a tool which could have its speed adjusted to the work being done on it has been brought to the attention of both tool builders and tool users. The present tendency is to furnish all of the heavier and larger tools with individually applied motors. This renders the location of the tool absolutely independent of any line shaft and also enables it to be placed in a position favorable to the handling of heavier work by

means of overhead cranes. The larger tools made for use in railway shop work may be said to be exclusively driven by means of individual motors. This is more fully realized by those who have endeavored to buy these tools arranged for belt drive, the manufacturer of the tool himself being opposed to thus equipping it, if it can be avoided.

One of the most powerful agents in the development of the present railroad shop has been the electric motor. By doing away with long line shafts and making possible individually-driven tools, it has enabled the service of the overhead crane to be utilized to the utmost. No shop is complete today unless it is equipped with a full complement of modern overhead cranes, which are useful, not only in lifting and moving locomotives, but in transporting work rapidly and economically from point to point, and even in the placing and lining up of the heavier pieces of work on the beds of the various machine tools.

As a rule a given unit of equipment is in the shop much longer than is actually required to perform the work necessary because of delays in getting the work through the shop or in procuring necessary material. As the time to complete the work is determined by the length of time required to finish the part which takes longest to go through the various shop processes, it is obvious that the handling should be done in the most expeditious manner possible. From the railroad point of view the most economical shop is the one which makes its repairs most thoroughly and rapidly, returning the equipment to service in the shortest possible time.

Many arguments may be given in behalf of the electrical equipment of railroad shops, but the very strongest reason for the use of this type of equipment is the single fact that those roads which have installed it, at first, perhaps, with many misgivings, are now its ardent advocates. On one of the largest systems upwards of 17-500 kilowatts are now in daily use for shop service alone, and all new shops are, without exception, being electrically equipped. In the last year approximately 16 000 kilowatts have been installed in thirty-three new plants, more than half of these being on roads which have similar euipments now in use. It is not at all unusual to see two or even more installations for the same system under way at the same time. In other words, the electrically-driven shop does not have to depend upon promises of what it may do, but the careful investigator can easily find out what it has done, and is doing. The best way to do this is to personally visit existing installations, and

as many of them as possible. Upwards of seventy-five roads (not shops) are today using electric drive.

Because, in former times, there may have been "an" experience with "a" motor, electric drive is not to be hastily condemned, but rather is there more reason that the situation be carefully studied and the requirements fully understood. "The" motor for the purpose required can then be readily found and conversion will be rapid and complete.

Among the advantages that may be advanced in behalf of the electrically-operated plant may be mentioned, briefly:—

The power plant may be located at the most convenient point.

The various buildings may be located with respect to the most economical operation of the shop as a whole.

An increase in equipment may be satisfactorily made at any time.

Overhead crane service may be used.

Increased economy of floor space.

Freedom of location of tools.

Ease of control of individually-driven tools.

Increased output.

Decreased unit cost of output.

Elimination of shafting and belt losses.

Increased illumination, natural and artificial.

Economy, flexibility and reliability.

The above arrangement is not to be considered as showing the relative importance of the various factors, but rather as indicative of some of the betterments possible where the electric drive is used to the best advantage.

In considering the equipment of an electrically-driven shop, it will be found that each installation contains local conditions which must be closely analyzed to secure the best results. There are available two general types of electrical apparatus, the alternating current and the direct current, each of which has its own peculiar advantages and its own field of special fitness. In most of the recent large installations a combination of these two systems has been used, the main generating units being of the polyphase alternating-current type with rotary converters for furnishing the required amount of direct current. When the amount of direct current required is a large percentage of the total power plant output, it is advisable to install independent direct-current units to take care

of this portion of the load during working hours, the "overtime" direct-current load being taken care of by means of a rotary converter.

As a general proposition, it is not considered advisable to equip all tools with individual motors, and only the larger and more important tools are so equipped, the others being driven in small groups by means of constant-speed motors. All individually-driven tools are operated by adjustable speed, direct-current motors unless the work done or the construction of the tool itself renders this unnecessary. On many tools there is now provided a speed box which permits the speed to be changed mechanically and enables the constant-speed motor, direct or alternating current, to be used in many cases where it was formerly handicapped.

Before making a final decision as to the exact type of plant to be used the proposed installation should be carefully studied, not only from the standpoint of immediate necessity, but the bearing of possible future developments should also be considered.

# LOADING STATIONARY INDUCTION APPARATUS FOR HEAT TESTS

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IN determining the heating of transformers and regulators during test it is desirable to approach as nearly to the operating conditions as practicable and, at the same time, to consume a small amount of energy during the heat run. This object has led to the use of compromise runs in which apparatus is operated at normal potential under no load to determine the heating due to core losses, and then run under short-circuited conditions for another period to find the heating effect of the copper losses. From the temperature rises under these two runs some idea of the heating under normal full-load conditions is obtained. In almost all cases however, some modification of the "loading-back" methods, as employed in the testing of motors and generators, may be used with the result that the apparatus is run under very nearly operating conditions and the energy supplied is only equal to that of the losses of the apparatus to be tested plus the losses taking place in a few small auxiliary transformers.

TESTING TRANSFORMERS IN PAIRS

The simplest of these loading-back schemes is the one commonly known and most easily applied to two transformers of the same voltage and rating. The connections for loading two such transformers are shown in Fig. 1. The low-tension coils will be referred to as the secondary windings, irrespective of whether the transformers are to be used for stepping up or stepping down the voltage. The secondaries of the two transformers are connected in multiple and fed from a suitable source of energy at the required voltage and frequency. This circuit supplies the core losses of the transformers. The primaries are connected in series with their potentials opposing, as indicated by the relative signs, and into this primary circuit is introduced, by means of the transformers shown, a potential equal to the sum of the impedance voltages of the units under test. (By impedance voltage is meant the voltage necessary to force the desired current through the coils when one winding is short-circuited.) Two transformers are used for this purpose to afford the generator protection from insulation strains due to the

high potential of the primaries of the main transformers. The auxiliary transformers may be fed from the same source that sup-

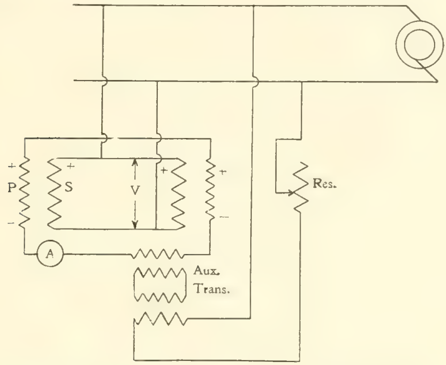



FIG. I—DIAGRAM OF CONNECTIONS FOR LOADING-BACK TEST ON TWO TRANSFORMERS

plies the core losses if a suitable rheostat or regulator is inserted to compensate for any discrepancy there may be between the machine voltage and the potential necessary for the auxiliary units.

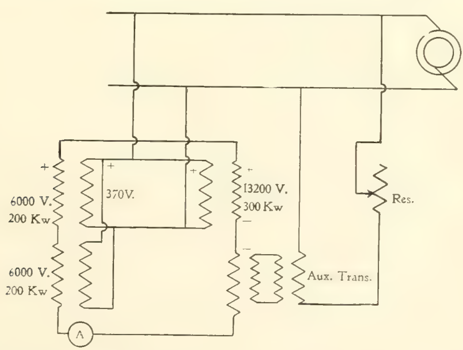



FIG. 2—DIAGRAM OF CONNECTIONS FOR LOADING-BACK TEST ON SINGLE TRANSFORMER BY USE OF TWO SHOP TRANSFORMERS

Preferably the auxiliary transformers are supplied from a separate machine and the potential regulated by field control in which case

this machine will furnish the copper losses of the transformers under test as well as all losses in the auxiliary units. With all losses furnished by one machine there is a slight difference in the current flow in the two secondaries on account of the magnetizing current, but this discrepancy is slight and no account is taken of it. The above method may be extended to any even number of like units, provided the source of power is suitable for supplying the losses. All of the secondaries are connected in multiple while the primaries are connected in series, each coil in opposition to those connected to it.

When a single unit is to be tested it is often possible to form a combination of shop transformers, or transformers of a different voltage and rating, in such a way that a large part of the energy represented by the full load of this transformer is returned to the source of supply. An example of such a combination is shown in Fig. 2. Here a 300 kilowatt, 13 200/370 volt unit is loaded by means of two 200 kilowatt, 6 000/370 volt transformers. The potential strain on the 6 000 volt units is, of course, increased over normal when their primaries are connected in series. Assuming that the load impedance voltage of the 300 kilowatt unit is 400 volts at full-load, then a water rheostat may be inserted in the primary circuit to take up the energy represented by full-load current of the primary circuit at 800 volts (13 000—12 000—400=800) or, preferably, a transformer combination, giving 800 volts in opposition to the 1 200 volts difference between 13 200 and 12 000 volts, should be connected as shown in the diagram and this would limit the current flow to normal value when full potential is applied to the secondaries. The auxiliary transformers would have to be fed from the same source as the secondary of the unit under test, with suitable rheostat or regulator control, since a definite phase relation between the voltage impressed on, and the voltage induced in, the primary circuit must be maintained. The energy furnished to the primary circuit in this case is somewhat greater than the copper losses of the transformers.

### TESTING TRANSFORMERS IN THREES

When three single-phase transformers of the same type are to be tested two of these may be connected as in Fig. 1 and the third may have its secondary connected in multiple with the low-tension coils of the first two so that it will be partially heated during the run of these two units. Afterward the heat run on this third trans-

former is completed by connecting it up with one of the first pair in the regular way.

If, however, a three-phase source of energy is at hand much time may be saved in the heat run of three like units by connecting them as shown in Fig. 3. The secondaries are connected in three-phase delta and normal voltage fed to them from a three-phase source. The primaries are also connected in delta but at one cor-

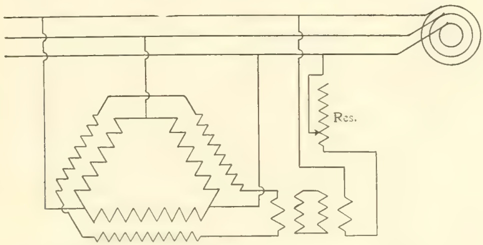



FIG. 3—DIAGRAM OF CONNECTIONS FOR LOADING-BACK TEST OF THREE TRANSFORMERS WITH THREE-PHASE SOURCE OF ENERGY USING RESISTANCE REGULATION

ner of the delta there is inserted a transformer combination such as will give the combined impedance volts of the three units and the desired current is caused to circulate in the windings. The auxiliary transformers may be fed from one of the three phases or from a

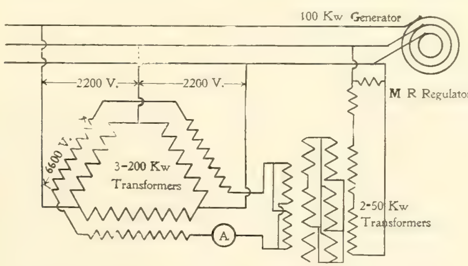



FIG. 4—DIAGRAM OF CONNECTIONS FOR LOADING-BACK TEST ON THREE TRANSFORMERS WITH THREE-PHASE SOURCE OF SUPPLY USING POTENTIAL REGULATOR

separate source. With three-phase transformers single units may be fully loaded by making the connections as described above. If either of the windings are to be connected in "Y" in the completed

unit this permanent connection should not be made until after the transformer has had a heat run.

The regulating resistance shown in Fig. 3 may be replaced, in some cases, by a potential regulator. In Fig. 4 is shown an example of connections for three 200 kilowatt, 60 cycle, 6 600-2 200 volt, air-blast transformers. The secondaries are connected in three-phase delta and fed from a 100 kilowatt three-phase machine normally giving 2 300 volts but reduced to 2 200 volts by means of the field rheostat. The voltage necessary to force 30.3 amperes full-load current, through the high tension winding of one transformer with the low tension coil short-circuited is 190. The total voltage required to be furnished by the auxiliary transformers is 560 for full-load and about 700 for 25 percent overload. The auxiliary transformers used in this case are two 50 kilowatt, 2 200/1 100—330/220/110 volt units and for normal load on the transformers in test they are connected step-down, step-up to give a ratio of four to one or furnishing 550 volts with 2 200 volts impressed. The magnetic potential regulator is connected in the 2 200 volt circuit and the potential raised until full-load current flows in the transformers under test. For the overload the connections of the low tension windings of the auxiliary transformers would be changed to three coils in the first transformer in series feeding two coils of the second unit in series, thus giving 733 volts with 2 200 volts impressed. The impressed voltage, in this case, would be cut down by means of the regulator, until the desired current flowed in the transformers being tested.

## TESTING FEEDER REGULATORS

Feeder regulators, which are adjusted by varying the number of turns in either the primary or secondary windings, may be loaded exactly the same as transformers. Single-phase induction regulators or magnetic regulators may be loaded by connecting the primaries in multiple and applying normal potential, while the secondaries are connected in series, opposing; one regulator is kept in the position of maximum boost and the other is varied until full-load current flows in the secondaries. The difference in primary currents may be considerable since the air gap causes such apparatus to have a large magnetizing current.

## TESTING INDUCTION REGULATORS

Three-phase and six-phase induction regulators may be readily connected up for heat runs in a manner similar to the above. Fig.

5 shows two six-phase regulators so connected. The primaries are in multiple and supplied with the proper six-phase potential. The secondaries are connected in six-phase "Y" opposing, and the regulators are adjusted until full-load current flows in the secondaries when normal voltage is impressed on the primaries. There will again be a difference in the currents in the primaries of the two regulators, due to the effect of magnetizing current, but the conditions are much more nearly normal than obtained by the compromise run, such as was described in a recent article on "Testing Large Motors, Generators and Motor-Generator Sets".* It is some-

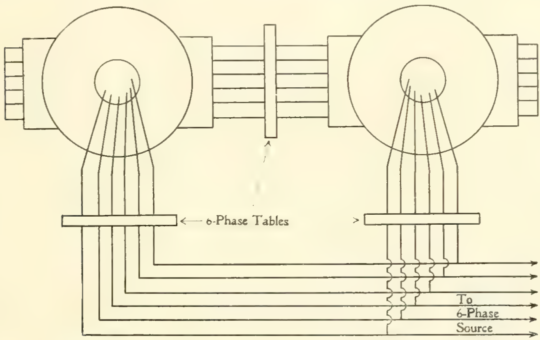



FIG. 5—DIAGRAM OF CONNECTIONS FOR LOADING-BACK TEST ON TWO SIX-PHASE INDUCTION REGULATORS

times feasible to substitute a bank of transformers for a regulator in making a run if but one regulator of a kind is to be tested.

In all heat runs on apparatus of this nature much time may be saved by starting the test at an overload or without having the cooling devices in operation and in all cases care should be taken to see that conditions are such that the desired overload tests may be made after the normal run with very few, if any, changes.

*See *The Electric Journal,* Vol. III., p. 653, November, 1906.

# THE MANUFACTURE OF ELECTRICAL PORCELAIN

DEAN HARVEY

THERE are two distinct classes of porcelain, the hard (or natural) porcelain the principal ingredient of which is kaolin mixed with quartz or other silicious material, and the soft (or artificial) porcelain, which varies in composition. The latter was originally intended as a substitute for the hard porcelain of China and Japan, and is of an inferior quality with a much lower fusing temperature. In the electrical industries the true porcelain is the only one used, and this form of porcelain only will be considered herein.

Porcelain consists essentially of four materials—kaolin (hydrated aluminum silicate), clay (alumina), quartz and a fusible silicate such as feldspar. The kaolin forms an infusible body which is rendered plastic by the addition of the clay, and quartz is added to prevent excessive shrinkage of the mixture. The feldspar provides a fusible material which serves to hold together the infusible particles of kaolin and quartz, and also causes the alumina to fuse.

## PREPARING THE MATERIAL

The materials in a finely ground condition are mixed with water and vigorously stirred. The mixture containing the fine particles in suspension is passed through screens to remove any impurities and material which has not been ground sufficiently fine, and is then passed into a cistern where it is constantly agitated to keep the clay from settling. The fluid is then pumped to a filter press where most of the water is forced out, leaving the moist clay in large cakes. Before the clay can be used, it is necessary to remove all air bubbles, as these would cause defects in the ware. This is accomplished by passing the clay through a machine called a "pug mill" where it is forced through a die under pressure.

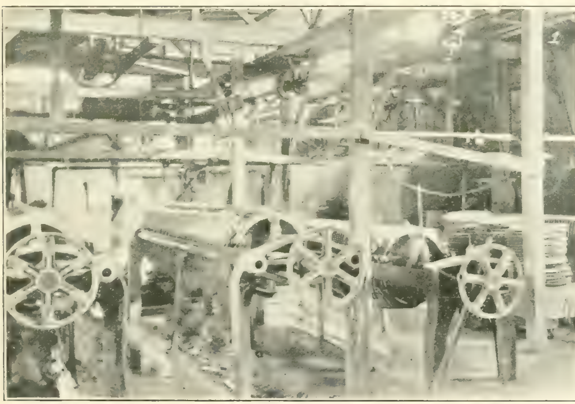
## FORMING

Several different processes are used for forming porcelain ware.

*Dry Pressed Ware*—The simplest method is that of pressing the porcelain out by means of a metal die. This is much the cheapest method of manufacture if a large amount of porcelain of one shape

is to be made. Such porcelain is not of the best quality as the clay is worked while rather dry and does not unite to form a sufficiently dense body for high grade porcelain. Dry process porcelain is best suited for use on circuits of comparatively low voltage (3 500 volts or less) as its dielectric strength is not high. Dies are particularly useful for making pieces of complicated form, such as bases for Edison plug fuse blocks, terminal blocks, etc., and there are many pieces which could not be made in any other way.

*Porcelain Tubes*—Small porcelain wiring tubes are made in tube machines, the clay being forced through a die which forms it into a long soft tube. The tube is left in the drying room until it becomes



FILTER PRESSES

fairly hard and is then cut into the required lengths and one end of each piece is upset in a machine to form the head.

When a long head is to be provided the clay tube is placed in a lathe and a strip of damp clay corresponding to the size of the head is wrapped around one end and turned to the proper shape with a forming tool.

*Line Insulators*—Porcelain line insulators are also made by means of a plaster mould, but by a method different from that used for tubes. The mould, having an inner surface corresponding to the outer surface of the insulator, is rotated upon a potter's wheel, which is simply a horizontal circular stand arranged so that it can be ro-

tated at high speed. A stationary tool is used to force the clay out to conform to the shape of the mould, at the same time giving the inside of the insulator the proper shape. After being formed the insulator, while still in the mould, is placed in the drying room, and in a few hours becomes dry enough to be handled, and shrinks sufficiently to allow it to be easily removed from the mould. The sections of the large multiple-part line insulators are also made in this way.

Corrugated pillars and bushings for high potential circuits are first blocked out by forcing the moist clay through a die into the

STEAM HEATED DRYING ROOM WITH PORCELAIN ON SHELVES IN PROCESS OF DRYING

form of a cylinder or heavy tube. The material is then dried thoroughly and is placed in a lathe and turned to the proper dimensions.

DRYING

After the porcelain pieces have been formed, they are placed on shelves in a steam heated drying room where they remain until completely dry. The time required for drying depends upon the size and thickness of the ware, and may be as much as three weeks if the pieces are unusually heavy. It is very important to have the ware thoroughly dry before firing, as any moisture will become vaporized and cause cracks and air spaces in the ware. During the operation of drying and firing the porcelain body shrinks about 12.5 percent and hence it has to be made proportionately larger to take care of this shrinkage.

### GLAZING

There are three classes of glazes in common use for glazing porcelain, viz.: the soft fire glaze, the hard fire or true porcelain glaze and a combination of the two known as white ware glaze.

The soft fire glaze is simply a soft lead glass, the glazing material consisting of a mixture of lead oxide and silica. It is objectionable because the glass does not have the same coefficient of expansion as porcelain, and is likely to become "crazed," that is, broken up by a large number of cracks. Another serious objection is that the lead in it may be attacked by the elements, acid fumes, etc.

The white ware glaze, which is principally used for glazing table ware, is open to the same objections as the soft fire glaze, as it is somewhat similar but with a smaller proportion of lead.

The hard fire or true porcelain glaze, consisting of silica and kaolin with a suitable flux, is the only glaze which is suitable for use with porcelain for electrical work. It has no constituents which can deteriorate, and has the same coefficient of expansion as porcelain.

A glaze is usually desirable on porcelain as the smooth glossy surface which it provides does not catch and retain dirt and moisture as readily as the unglazed surface, and may easily be cleaned. The glaze also affords a convenient means of coloring the ware. Brown glaze is usually used for outside work to make the insulator less conspicuous. The coloring material for this glaze is quite sensitive to the kiln gases, so that variations in the conditions during firing are very likely to cause a considerable variation in the color of the glaze.

Insulators which are to be glazed are dipped in the glazing solution after the clay has been thoroughly dried. They are then dried again before firing.

### FIRING

The kilns used for firing porcelain ware are of cylindrical form, from ten to sixteen feet in diameter, lined with fire clay, and having fire boxes at the sides in which fires are maintained to heat the interior. The ware is placed in large fire clay receptacles called "saggers" and the interior of the kiln completely filled with these "saggers." The doors are then bricked up and sealed and the temperature is gradually raised to about 2 400 degrees F. and is maintained for a few hours at the maximum value so as to penetrate through the ware. The fires are then extinguished, and the kilns are allowed to cool down slowly, so as to avoid all possibility of causing internal

strains within the porcelain. The condition of the ware in the kiln is usually determined by examining small test pieces of porcelain which are withdrawn from the kiln through small openings at the side. As the change in temperature has to be made very slowly to prevent injury to the porcelain, the process of firing requires considerable time, sometimes taking as much as four days when large pieces are being fired.

In the manufacture of electrical porcelain for high potential service the greatest care has to be taken in the selection of materials to provide a "body" which will have high dielectric strength and at the

KILN BRICKED UP READY FOR FIRING

same time will have ample mechanical strength, as many insulators, especially those for line insulation, are subjected to heavy mechanical stresses. When used on circuits of extra high potential it has been found necessary to make the porcelain in several parts, held together by means of the glaze or cemented together; as with increase in size and thickness of the material come increased difficulty in obtaining thorough drying and vitrification, and it is also very difficult to prevent cracks or other flaws in the material.

The above description will give a general idea of the process of manufacture of porcelain. The consideration of the electrical design and testing of porcelain will be reserved for a subsequent article.

# EXPERIENCE ON THE ROAD

## SOME EXPERIENCE AT SHAWINIGAN FALLS

CHAS. F. GRAY

Superintendent of Construction, Canadian Westinghouse Company, Ltd.

THE Shawinigan Falls, where the power plant of the Shawinigan Water & Power Company is located, are eighty miles north of Montreal at the junction of the Shawinigan and St. Maurice rivers. This plant is becoming one of the most important in the Dominion of Canada. Power is transmitted at 50 000 volts from the Falls to Montreal where it is used for street railway and power purposes. There are five two-phase 30 cycle alternators installed having an aggregate capacity of 25 000 kilowatts. These are direct-connected to water wheels operated under an average head of 130 feet. The fifth generator which is of 6 600 kilowatts capacity has just been installed within the last year.

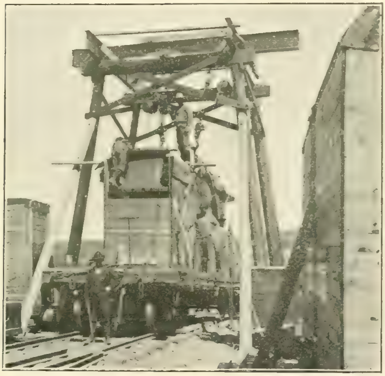


FIG. 1—UNLOADING GALLOWS WITH TRANSFORMERS IN POSITION FOR UNLOADING

Some points regarding the installation of this generator which was under the writer's direction may be of interest. The power house is so situated that the installing engineers had many difficulties to contend with, chiefly in the lowering of the apparatus to the power house, as it is near the water's edge below the falls and about 160 feet below the level of the tracks on the embankment above, where the apparatus was delivered on cars. It was necessary to get the apparatus down a steep grade from the cars at the top of the hill and into the power house.

An excellent unloading tower was rigged up by Mr. R. C. Argall, superintendent of construction of the Shawinigan Company for use in unloading and lowering the heavy apparatus to the power

house. This is shown in Fig. 1 with a car load of transformers in position ready for unloading. At the head of the incline two sets of anchor posts, each composed of three heavy pine snubs, were placed in the ground to a depth of about six feet and about seven feet apart. These posts were imbedded in concrete blocks three feet square. Across the posts was placed a heavy I-beam and to the center of this the upper block of the lowering tackle was fastened as shown in Fig. 2. The apparatus being lowered was attached to the lower block. Five thousand feet of two and one-half inch rope was used on this lowering tackle. The fall end of the rope was passed around three heavy snubbing posts in succession, and the loose end held by three or four men. The posts were set seven feet in the ground and solidly imbedded in concrete. With this outfit six car loads of heavy apparatus, varying in weight from 15 to 60 tons, were unloaded in two days of ten hours each. The loaded cars were run under the tower or lifting gallows and the apparatus lifted off the cars, lowered to the ground and rolled to one side as shown in Fig. 1.

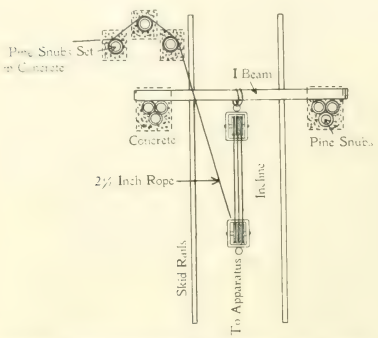


FIG. 2—ARRANGEMENT OF TACKLE FOR LOWERING APPARATUS

The ground from the railway track down to the power house, 525 feet distant, was very rough, but by a great deal of work and gradual development a first-class skidway was made on which the apparatus was lowered. Fig. 3 shows this skidway at the time one of the water wheel draft tubes was being lowered. This view also shows the gate house and penstocks leading to the older power house and the new addition, as well as giving a general idea of the magnitude of the work.

In Fig. 4 is shown the method of unloading the 55-ton top case of one of the water wheels. An evidence of the effective way in which the apparatus was handled is given from the fact that the time taken to lower this piece of apparatus, from the placing of the

slings to receiving at the power house entrance, was only thirty-five minutes.

A great deal of unloading was done in the midst of a Canadian winter and while the ice and snow made it easier to skid apparatus, at the same time it called for considerable extra care on the part of those engaged in the work. Most of the rough labor employed on this work was the typical "Habitant" of Northern Quebec, who makes up for his lack of English by his willingness to work.

One feature of interest in connection with the installation of the 6 600 kw generator was that this machine was wound after

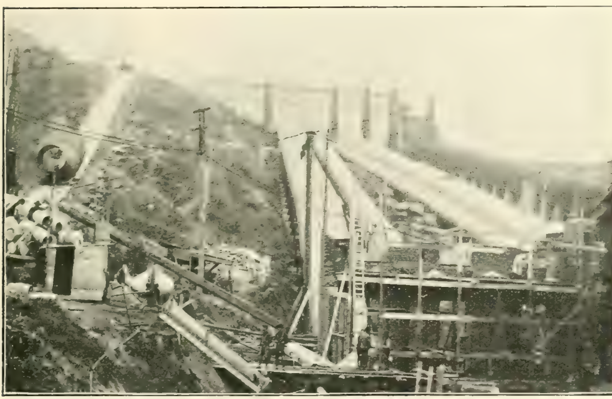


FIG. 3—GENERAL VIEW OF GATEHOUSE, PENSTOCKS LEADING TO THE OLDER POWER HOUSE AND TO THE NEW ADDITION

Showing skidway at the time one of the water wheel draft tubes was being lowered.

reaching the power house, the armature and field coils being sent from the factory. This generator is shown in course of installation in Fig. 5. After the field coils and the copper dampers were in place the dampers had to be turned down to the exact size. This was rather a ticklish proposition on a generator of such large size as it was very difficult to get the water wheel to run slow enough for turning purposes. Another difficulty was that the cut was an intermittent one as the tool would jump from damper to damper as the field revolved. However, a tool rest was rigged up in front of the revolving field and the speed kept as low as possible by regulat-

ing the water supply. The wooden support for the tool rest is shown in position in Fig. 5. It was necessary to remove about one-sixteenth of an inch of material. The operation proved successful and the work was done as neatly as if it had been done in an electrical factory, the chief drawback being that the speed was rather high for such work.

FIG. 4—UNLOADING TOP CASE OF WATER WHEEL

Another feature of interest in this installation was that one bearing of the generator had to be raised one-fourth inch higher than the other in order to bring the couplings in line. This became necessary because the water wheel shaft had a sag of one-eighth inch due to the weight of the runner and hence the face of the coupling on the water wheel was thrown slightly upward. The generator was the machine which had to be moved, because it was necessary to keep the turbine bearings level in order that another machine could be coupled on at the other end.

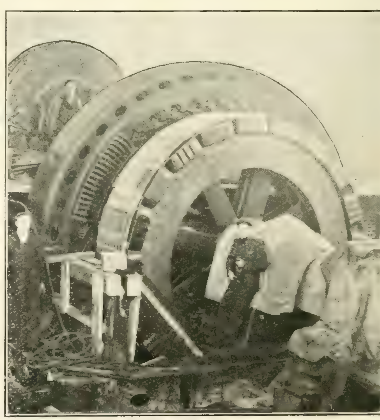


FIG. 5—INTERIOR OF STATION SHOWING ONE 6600 KW GENERATOR IN COURSE OF ERECTION

THE
# ELECTRIC JOURNAL

VOL. IV. JULY, 1907 NO. 7.

**Physical Characteristics of Dielectrics**

In many instances theory follows practice, and this is particularly true in regard to our knowledge of dielectrics. We have known for years that under certain conditions certain dielectrics would give such and such results, but there has been much that was mysterious due to our imperfect knowledge of the subject. Exact information in regard to the properties of dielectrics on which laws may be based is very difficult to secure, on account of the many uncertainties entering into any given set of tests. Splendid work has been done in promoting our general knowledge of the subject through the efforts of O'Gorman, Jona, and others; and through the work done during the last few years the theory of the subject has been very greatly advanced.

The best results are obtained only when theory and practice go together, and readers of the JOURNAL who are interested in the subject should welcome the paper by Mr. Fleming, giving as it does in clear and concise form the modern theory of dielectrics as based on both practical and theoretical consideration. Much of this information has been available through the scattered papers which have appeared on the subject during the last few years, but Mr. Fleming's paper brings the whole subject in such form that the ordinary reader can get at the facts in logical order and in a short time. A careful perusal of the paper is recommended to those who are interested in the physical characteristics of dielectrics, particularly as they apply to dynamo-electric machinery.

C. E. SKINNER

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**Harmonics in Three-Phase Systems**

In most engineering operations there are two fairly distinct classes of phenomena; first, those which are fundamental or normal, and, second, the variations from this normal condition. In the consideration of alternating-current phenomena, the fundamental laws and relationships are based upon simple sine waves of electro-motive force and current. The various currents and voltages which result from an impressed sine

wave can be followed through circuits having various characteristics of resistance, inductance and capacity. In many cases in ordinary practice the variations from this fundamental condition are slight.

A variation from this elementary condition occurs when the wave form is not of the simple sine shape. The simplest modifications are those in which an additional sine wave of two or three or more times the fundamental frequency is introduced. Usually the harmonic produces its effect through the system in a manner similar to the fundamental or main wave, except that the proportions are modified by the inductance and capacity.

An interesting and curious condition exists in three-phase circuits. The fundamental and the third harmonic have quite different characteristics. One connection of circuits is impervious to the harmonic although freely admitting the fundamental; while another connection allows the harmonic current to flow without the fundamental. The general principles are presented in the article by Mr. Grier in the April issue of the JOURNAL. A particular case is described in the present issue by Mr. Rhodes. The 5 000 kw generators described in the present article generate similar electro-motive forces in each of the three branches of the armature winding, which are connected in the ordinary star form. The electro-motive force measured between the neutral point and either of the main terminals of the generator contains both the fundamental and the various harmonics. The electro-motive force measured between the main terminals of the generator, and therefore including in series the electro-motive forces generated in two of the branches of the armature winding, contain the fundamental and certain harmonics, but others do not appear for the reason that they oppose one another in the two branches; or, in other words, the third harmonics (and those which are a multiple of three) tend simultaneously towards the central or neutral point in all three branches.

If two three-phase generators be connected in parallel on three bus-bars, the third harmonic does not appear in the bus-bar electro-motive force. It does occur, however, in the electro-motive force measured between a neutral point and either bus-bar. If the two machines are operated under exactly similar conditions there is no occasion for current to flow between the neutral points. If, however, the two generators have third harmonics of different value, then the electro-motive forces between the neutral and the three main terminals of the first generator do not correspond with those in the second generator. Each of the three branches of one

generator is in parallel with one of the three branches of the second generator. These three circuits have a common connection in the conductor connecting their neutral points. Consequently, it affords a path for the currents which tend simultaneously to flow toward the center in all three circuits. If, therefore, the third harmonics in the two machines are not equal, the current flows in each of the three branches of the winding through the neutral conductor from one generator to the other and returns through the three bus-bars.

The conditions which give rise to unequal third harmonics are due to field distortion caused by the armature current. If the armature currents in the two machines are similar, then the electro-motive forces generated will be similar. If, however, the armature currents are not similar, for example, if the load on one machine is large while that on the other is small, or if the currents delivered are of different phase, or if there is a local current of fundamental frequency flowing between the machines, which is therefore leading in one machine and lagging in the other, then the field distortion and the electro-motive forces produced are not the same in the two machines. A connection between the neutral points allows these unequal electro-motive forces to cause a flow of current at three times the normal frequency. This current returning through the bus-bars affects the form of the bus-bar current. This high frequency current, however, does not get beyond the bus-bars to the load if there be no connection between the neutral point of the generators and the load.

It may be noted that these 5 000 kw generators run well in parallel under various conditions of load, excitation and engine conditions when the neutral points are not connected together but encounter difficulties when the neutral points are connected and the conditions in the individual machines are materially dissimilar. Fortunately, however, it was found that the protection sought could be secured by the grounding of the neutral of a single generator instead of all of the generators in parallel, as was at first proposed.

The oscillograph records in connection with the present article show the remarkable facility of this instrument for investigating problems of this kind and show in a clear manner the peculiar results which sometimes follow from what seems to be a simple modification of normal conditions.

Chas. F. Scott

# PHYSICAL CHARACTERISTICS OF DIELECTRICS

A. P. M. FLEMING

Engineer with British Westinghouse Electric & Mfg. Company, Ltd.

THE rigid classification of materials into "conductors" and "non-conductors" is responsible for a prevalent idea that the former only are capable of electrical conduction. Strictly speaking all materials are conductors in the sense that they are to some extent able to transmit electricity, and to adequately appreciate the physical characteristics of dielectrics it is essential to form some conception of this conducting process.

Experimental evidence* is conclusive that current is transmitted through gases by means of electrically charged particles, and †modern theories substantially agree that the conducting process is the same for all substances whether they are in a gaseous, liquid or solid state. These charged particles which have been termed "ions" are assumed to consist of atoms or combinations of atoms or of infinitely smaller negatively charged particles known as electrons. It is conceived that all atoms contain one or more detachable electrons whose aggregate negative charges are balanced by an equivalent positive charge possessed by each atom, and the addition of an electron, or its removal from one of these neutral atoms or combinations of atoms forms an ion possessing an excess positive or negative charge.

If the cohesive force uniting atoms and their electrons is overcome, the ions thus formed are free to move under the influence of an electric force and when in motion in a definite direction constitute what is ordinarily termed an electric current the magnitude of which is determined by the number and velocity of the ions. In substances such as metals of simple molecular structure the cohesive force between atoms and electrons is apparently very weak and consequently there are always a large number of ions in a practically free state, whereas in dielectrics which are usually of a very complex nature, comparatively few ions are free and a considerable force is required to liberate the electrons. The stress on the molecular structure tending to effect this liberation depends on the intensity of the electrostatic field produced by the application of a dif-

*See "Conduction of Electricity Through Gases" by J. J. Thomson.
† See "Electron Theory" by E. E. Fournier d'Albe.

ference of potential to the opposite surfaces of the dielectric, and the property which the material possesses of being able to resist this disruption of its structure is known as its dielectric strength.

The distortion of the molecular structure prior to disruption, whatever its precise nature may be, accounts for the charging or displacement current familiar in condenser working, the magnitude of which, for a given area of electrodes and thickness of dielectric, depends on the specific inductive capacity of the material.

When the field is due to an alternating e.m.f., a certain amount of energy will be expended in producing these periodic molecular distortions. In materials of high conductivity the current will increase directly as the applied voltage, that is to say the "resistance" offered to the formation and velocity of the ions is constant. In

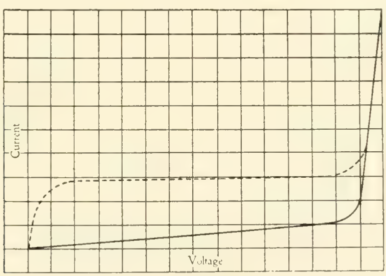


FIG. 1—TYPICAL CONDUCTION CURVE FOR GASEOUS DIELECTRICS

dielectrics, however, this is true only when conduction is due to the initially free ions, and the resistance will rapidly decrease when the field is intense enough to effect the liberation of the electrons. The degree of conduction and the phenomena accompanying it depend on whether the dielectric is in a gaseous, liquid or solid state.

## GASES

A typical conduction curve of gases is shown in Fig. 1, which indicates that for weak fields the current, due to the ions which are already in a free state, increases directly as the voltage, that is to say, over a given range the "resistance" is constant. The amount of current flowing during this period is so small that to facilitate experimental investigation it is usual to increase the conductivity by introducing ions from an external source. These may be de-

rived from radio-active substances, or incandescent solids either of which spontaneously emit ions, or the same results may be obtained by exposing the gas to an electrical discharge or to ultra-violet light.

The conductivity of a gas thus ionized is shown by the dotted portion of curve, Fig. 1, which indicates that, while the current increases very rapidly at first for a slight increase in voltage, a stage is reached when the ions are utilized at the same rate as they are produced by the ionizing agent, and practically no increase of current occurs even for considerable increase in voltage.

When, however, the field becomes sufficiently intense for electrons to be liberated, the conductivity very rapidly increases as is indicated by the upward bend of the curve. The increase in current is demonstrated first by a glow and, as the voltage increases, by a brush discharge which forms a conducting envelope around the opposing faces of each electrode and thereby virtually reduces the effective thickness of the dielectric. This concentrates the field between these two points and its intensity increases as the distance between the conducting envelopes is reduced and culminates in the disruption of the medium as shown by the passage of a spark between the electrodes. After the first breakdown the succeeding sparks usually follow at a lower voltage owing to the ionization produced by the first discharge.

The disruptive voltage depends to some extent on the distribution of the field which is determined by the shape of the electrodes, since the lines of force are assumed to start normal to their surface, i.e., when the electrodes consist of flat plates or spheres of large radius the field will be practically uniform; when small spheres or points are used, however, it will be very intense near the electrodes and comparatively weak midway between them. Since the formation and the velocity of the ions depends largely on the intensity of the field, the conductivity will increase and the voltage required for disruption be reduced as the radius of curvature of the electrodes gets smaller. The relation between disruptive voltage and sparking distance for various shaped electrodes is shown by the curves in Fig. 2.

Within wide limits the disruptive voltage varies directly as the pressure of the gas. When, however, this is reduced to a "critical" value of the order of a small fraction of an atmosphere, the disruptive voltage increases as the pressure is diminished. This is due to the fact that sufficient ions cannot be produced from the small quantity of gas available and disruption does not take place

until the intensity of field is raised high enough for the necessary quantity of ions to be liberated from the electrode surfaces. At the critical pressure there is just sufficient gas to provide the ions required, and their velocity in the rarefied medium is high, consequently the voltage required for disruption is a minimum. At higher pressures while there is more gas available for ionization, the velocity of the ions is reduced owing to the greater density of the medium and the disruptive voltage consequently increases.

It has been suggested that the luminous strata between the electrodes in rarefied gases, indicates the regions where the ions hav-

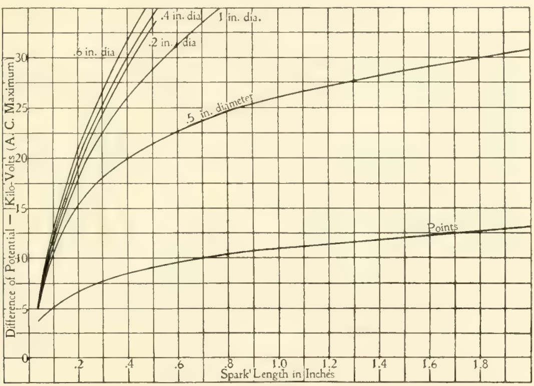


FIG. 2—RELATION BETWEEN SPARK LENGTH AND DISRUPTIVE VOLTAGE IN AIR FOR DIFFERENT SIZED ELECTRODES

ing acquired sufficient kinetic energy by virtue of their high velocity, are active in ionizing the neutral atoms of the gas.

When the spark gap is only of the order of a few mils, the disruptive voltage is independent of pressure, but varies with the metal used for electrodes, and the ions supporting conduction appear to be derived from them.

There is an appreciable "lag" between the time when voltage is applied and when disruption occurs, which is slightly in excess of that which a gap will indefintely sustain. The duration of the lag depends largely on the dryness of the gas, and whether any ionizing agent such as ultra-violet light is present, or any influence tending to alter the distribution of the field.

The change in molecular structure when air is subjected to electrostatic stress produces certain chemical effects. If the stress is just sufficient to liberate the electrons, ozone is formed, the intensity of the field at this stage producing an almost imperceptible glow or what is sometimes termed a "silent discharge." The molecular change* when the stress is increased and a brush discharge occurs results in the formation of oxides of nitrogen and possibly nitric acid under favorable conditions of moisture and temperature.

### LIQUIDS

Except in the case of certain mineral and vegetable oils little experimental investigation has been made with regard to conduction through liquid dielectrics. In these cases, however, the process is on the same general lines as in gases, and the conduction curve takes the same general form as shown in Fig. 1. With weak fields the resistance over a certain range of voltage is constant for given conditions, but its magnitude varies considerably with temperature as shown in Fig. 4, this being due either to the change in density or to the difference in the molecular activity which, of course, varies with temperature. As the applied voltage is raised and electrons are liberated conduction rapidly increases, the field becoming more and more concentrated as the conducting envelopes around the electrodes increase in size, until finally a breakdown of the medium occurs.

A higher voltage is usually required to repeat the disruption immediately after the first discharge, due either to the dispersion of impurities which tend to line up between the electrodes in the most intense portions of the field, or to some change in local conditions governing the liberation of the electrons. It is not, however, due to the pressure of moisture in the liquid as is often supposed.

The disruptive voltages for different spark lengths for a certain class of oils are shown in Fig. 5. These results indicate, that for tests made under commercial conditions, the spark length does not increase in proportion to the voltage. When, however, the voltage is high enough to produce practically instantaneous disruption, the curve very nearly follows a straight line law. The disruptive volt-

* See "Electrical Discharge in Air" by Cramp & Leetham. Electrochemical & Metallurgical Industry. October, 1906.

age for oils,† for very short spark lengths is shown in Fig. 3. An increase in density of the dielectric, and in the radius of curvature of the electrodes tends to increase the disruptive voltage for a given spark length. The effect, however, is not so marked in liquids as in gases.

The disruptive strength of oils does not appear to be affected appreciably by heating either when this is produced by an internal dielectric loss or by any external cause unless the temperature is high enough to bring about some physical or chemical change in the dielectric.

SOLIDS

The effects produced by electrostatic stresses are much more marked in the case of solid than in liquid or gaseous dielectrics owing to the fact that chemically the former are more complex and

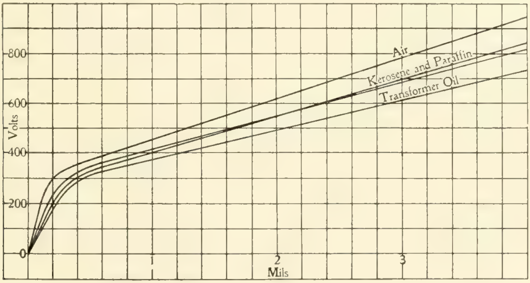


FIG. 3—DISRUPTIVE VOLTAGES FOR VERY SHORT SPARK LENGTHS IN GASEOUS AND LIQUID DIELECTRICS

Electrodes:—Plate 2 in. diameter
Sphere 1 in. diameter

structurally are less homogeneous than the latter. Conduction, as in the case of gaseous and liquid dielectrics, is due to the motion of ions, and varies with the applied voltage much in the same way as on these materials. With weak fields the resistance for given conditions is constant over a certain range in voltage. Its value, however, varies considerably according to the temperature and hygroscopic condition of the material. The effect of temperature is

† See "Spark Potentials in Liquid Dielectrics," R. F. Earhart, Physical Review, November, 1906.

shown in Fig. 4, which indicates a decrease in resistance as the temperature increases up to about 80 degrees C. The upward bend at higher temperatures is due partly to the moisture being dried out, and partly to a change in the nature of the material. The ultimate downward bend occurs when the material has become carbonized and at that temperature is a partial conductor.

As the field becomes more intense the conductivity increases very rapidly and breakdown finally occurs. In the case of gases and liquids disruption is ultimately due to the concentration of field and consequently the rapid production and velocity of ions resulting

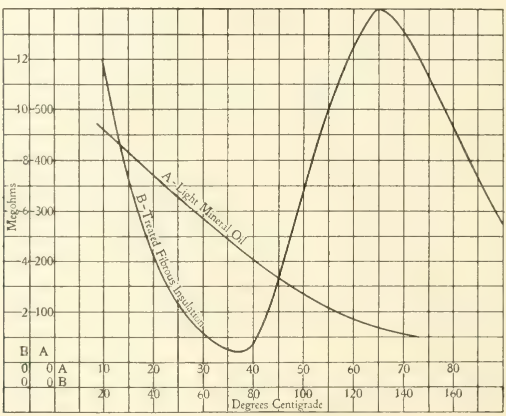


FIG. 4—TYPICAL CURVES SHOWING VARIATION OF RESISTANCE WITH TEMPERATURE FOR SOLID AND LIQUID DIELECTRICS

from the formation and enlargement of the conducting envelopes around the electrodes, and, while this occurs to some extent in solid dielectrics, breakdown is more often brought about either by heating, chemical change, or mechanical disruption or by a combination of some or all of these causes. The internal loss occuring in all dielectrics when subjected to electrostatic stresses, according to recent experiments, is represented by the formula,—$W = a\ K\ V^2$,* where,—*a* is a constant, depending on the nature of the material, *K* its electrostatic capacity and *V* the impressed voltage. This energy

*"Dielectric Losses," by Dr. Paul Humann, Electrician, (London), Nov. 16, 1906; also "Energy Losses in Commercial Insulation Materials," by C. E. Skinner, Transactions of A. I. E. E., May, 1902.

is expended in heating the dielectric, and its effects are more marked in solids than in liquids or gases. In the latter materials, the heat, while produced most quickly where the field is most intense, is dissipated by convection currents over the whole of the dielectric, whereas in solids, owing to the very poor thermal conductivity, the heating is localized and may result in the carbonization of the interior of the material, thereby reducing the effective thickness of the dielectric and consequently increasing the stress at this point. The "lag" in the case of solid materials is much more pronounced than with liquids or gases. It is reduced, however (due to structural changes which facilitate the ionizing process), if the external temperature is high, and is increased if effective ventilation is provided.

In dielectrics containing much volatile matter there is a danger, if local heating occurs, or if there is any chemical change resulting from a molecular re-arrangement due to the formation of ions, of an easily ionizable vapor being formed which will permeate and quickly reduce the dielectric strength of the whole medium. This is particularly liable to occur if the material contains undried varnishes or moisture and is always accompanied by considerable heating of the dielectric.

In other solid dielectrics, especially if voltage is only instantaneously applied, there is little attendant heating or chemical action, and the breakdown is apparently of the nature of a mechanical disruption, the structure giving way simultaneously throughout the insulating medium. Unless, however, the exact nature and condition of the dielectric is known it cannot be stated with any certainty to what cause disruption is ultimately due.

Excepting when the pressure is instantaneously applied, the disruptive voltage does not vary directly as the thickness. This is indicated by the curves, in Fig. 5. The exact shape of the curve will vary according to the ventilation of the material, the cooling effect of the electrodes, the external temperature and the intensity of the field which, neglecting the effect of surface discharge, will be determined by the shape of the electrodes and thickness of dielectric. *The law,—$V = ad^{\frac{2}{3}}$, where $a$ is a constant depending on the dielectric and $d$ its thickness, has been suggested as giving approximately the relation between disruptive voltage and dielectric thickness.

* See article by C. Baur in the Electrician (London), Sept. 6, 1901.

In homogeneous dielectrics the stress across various thicknesses will depend on the field distribution and will in general be greatest near the electrodes. Where, however, the medium consists of layers of several materials having different specific inductive capacities, the stress will, in addition, tend to be distributed across each layer inversely as its capacity. Some layers therefore may be strained beyond their disruptive limit and ions formed which will impart a conductivity to the whole medium and in addition heating will occur in these layers, which will be transmitted to surrounding ma-

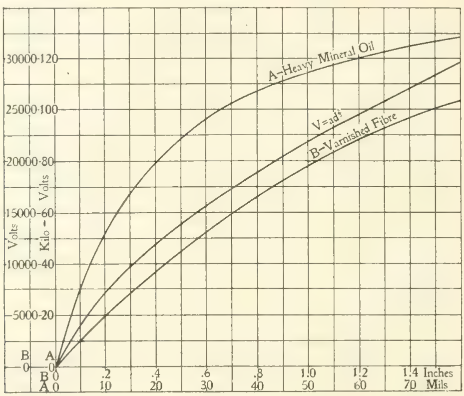


FIG. 5—TYPICAL CURVES SHOWING RELATION BETWEEN DISRUPTIVE VOLTAGE AND THICKNESS OF MATERIAL FOR SOLID AND LIQUID DIELECTRICS

$A$=Electrodes, 1 inch sphere
$B$=Electrodes, 1 inch flat plates

terial and consequently reduce the dielectric strength of the entire insulation. This is very liable to occur in high tension apparatus, particularly when this is subjected to prolonged high pressure insulation tests, since it is impracticable in commercial working to employ entirely homogeneous insulation. The various dielectrics should therefore be selected and so arranged as to tend to distribute the stresses as uniformly as possible throughout the entire insulating medium.

# THE RAW MATERIAL SUPPLY*

P. H. KNIGHT AND C. E. SKINNER

IF it were feasible to present here a complete list of the different materials which form the component parts of the product of any large manufacturing company together with those which are consumed in the manufacturing processes, or of those which are used by any great railroad, the range and variety displayed would doubtless surprise those not closely connected with such work. The list for a company with which the writers are somewhat familiar contains not less than 850 items. This list is made up of definite and distinct classes or grades of materials, the various shapes and sizes of any class all being included as one item. The purpose of this paper is to present a few considerations involved in the procuring of a supply of raw material so large and varied. The term Raw Material will be used to cover all material purchased on which work has to be done by the manufacturing company, as copper wire, pig iron, insulating paper, brass rod, porcelain, sheet steel, cast steel, etc., or which is consumed in the manufacturing process, as cutting compounds, fuel oils, coke, etc.

From the manufacturer's point of view there are in general two sets of conditions involved in the selection of a raw material: First, the engineering, which requires that the material have characteristics suitable for the purpose intended; and second, the commercial, which requires that the material selected be one that can be obtained in sufficient quantity—preferably in the open market and on satisfactory terms.

The most convenient method for designing engineers to designate the material to be used in a particular case or to make known the conditions to be fulfilled by it, is to refer to the title and serial number of a Purchasing Department Specification in which the characteristics of the material are described and the tests to which it must conform are specified. This presumes, of course, the previous preparation of a Purchasing Department Specification under the general conditions governing such specifications. If specifications could be prepared that would cover all classes and grades of

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*From a paper read before the American Society for Testing Materials, June 20, 1907. This article was prepared especially for the JOURNAL, and afterward it was decided to present it as a paper before the above Society.

material required and be so worded that they would be satisfactory to all parties concerned, the work to be done in connection with the supply of raw material would be mostly of a routine nature, merely checking the shipments received in line with the requirements of the specification. Unfortunately, however, where the materials are of a very great variety, it is often quite impracticable, for many of them, to use a specification at all. In many cases materials are used by manufacturers for purposes for which they are not ordinarily designed, as for example, the use of wrapping paper for insulating purposes. The paper maker is not usually familiar with insulating work and has no means of making tests which will indicate to him whether or not his product is satisfactory for the purpose intended by the purchaser. It is also frequently difficult to devise a test that will readily and accurately determine the suitability of a material; or, granting that such a test can be made, it may not be generally recognized by the trade, and the manufacturers of the material, not being prepared to make the tests, may not be disposed to do business on this basis. Again, while the tests may be satisfactory to all concerned, the cost of making them may be more than any probable loss or risk involved in buying without a specification.

In such cases, the obvious course is to buy a grade or brand which has a definite standing in the trade, if such can be found, which shows characteristics suitable for the purpose intended. The purchaser of the material must then determine for himself whether or not the commercial variations in the brands selected are such as to interfere with his manufactured product. In some cases this method of buying by brand or grade is more satisfactory than buying by specification, especially where the commercial variation in standard materials is not too great for the use in view. On the other hand, when materials are susceptible of adulteration, competition may lead the manufacturer or dealer to adulterate to such an extent that trouble results in the use of the material. The trouble and loss which may result from the use of such adulterated goods is sometimes many times as great as the value of a month's or a year's supply of the goods in question. In a certain process a brand of shellac was used which was known to contain some adulteration and this adulteration seemed to be beneficial to this particular process. The amount of adulteration was increased in certain shipments, with the result that serious trouble was experienced in the manufacture of the product and the brand had to be abandoned for one more reliable and which could be adulterated by the user as occasion required.

It is sometimes very difficult to draw a specification so that shipments of material obtained under it from different sources will correspond close enough to each other to be satisfactory, even though each may technically fill the specification; and this also involves the question as to whether materials made by different manufacturers may be used together or must be used separately; as, for example, varnishes, glues, metals, etc.

Each material may be satisfactory for use with its special characteristics in mind, and totally unsatisfactory if mixed with other goods of the same class or if not used correctly. Consequently, the shop methods and processes involved in a large factory may be a determining factor in the use of a particular brand or brands of material. From the manufacturing standpoint it is, of course, undesirable to have materials of the same general class which have to be used separately, while, on the other hand, it is undesirable to be limited to any one source of supply for a material, as this situation is quite likely to result in a higher price than would obtain with competition. Furthermore, a strike or some accident, such as a fire, might at any time entirely shut off the supply, thereby delaying the completion of apparatus and necessitating the use of some untried material. It is very desirable, therefore, to try out materials from different sources, to map out their characteristics and to determine whether or not they can be used together and under the same conditions. If this can be done the brand or grade may be placed on an approved list and the purchasing department instructed to buy from any of the approved sources, as market conditions may dictate. If, for the reasons outlined above, materials cannot be used together but may be used as substitutes for each other, care must be taken that the supply of one brand or grade is exhausted before another is introduced, and that those interested in the use of the materials are properly instructed when, for any reason, a change from one to the other is made.

It is frequently impracticable to approve all the possible sources of supply for a given material on account of the large number, and, when this is the case, a sufficient number of sources should be investigated so that the necessary competition may be secured in the buying of the material in question. One difficulty in following out this plan lies in the fact that there may be sources of supply which have not been investigated and not approved which may be just as satisfactory as those on the approved list. In such cases commercial conditions must dictate the policy in extending the list.

In purchasing material by brands or grades or even on specification, the method of handling may be somewhat different, depending on whether the material is manufactured by the party furnishing same or whether he is only a dealer or importer. If the material is not satisfactory, or if modifications are required, the manufacturer may be able to make such modifications without difficulty, as, for example, a change in the flash point of an insulating oil. The dealer or importer may not be able to control such modifications and, consequently, the brand may have to be changed, as, for example, a brand of tin.

The purchase of a brand of material without a specification or without investigation for approval always involves more or less risk and sometimes extra labor. This labor consists in lining up any characteristics not familiar to the workmen and in following up the troubles which may occur due to the effect of such characteristics, even though the material may become entirely satisfactory when the workmen become familiar with its use. The risk lies in the possibility that different shipments from an untried source may vary in quality, to the detriment of the completed product, or that an increase in cost of production may be caused by some variation which may escape notice in testing and inspecting the raw material. Greater familiarity with the requirements makes such a variation much less likely to occur where a material has been obtained over a long period of time from one source, even though the seller's reputation in the general trade may be in no way superior to that of others.

From the standpoint of the producers of raw materials, specifications are distinctly advantageous to firms that will not reduce the quality of their product below accepted standards in order that they may cut prices. Where several brands are approved for purchase without specifications on the basis of price only, a premium is liable to be placed on the adulteration of goods or the lowering of their quality in order to meet competition. Specifications fairly drawn and strictly enforced are a protection to honest firms against unfair competition. Specifications play so important a part in the purchase of a material that it may be worth while to give an outline of some of the steps necessary to secure satisfactory specifications and some idea of the way in which they are commonly used.

It is usually impossible for any one—no matter how familiar he may be with any particular material—to draw a specification for that material without spending considerable time in making tests and securing approval, although the idea seems to prevail among

many that all that is necessary is for an engineer to write out the characteristics which he wishes fulfilled in the material in question. To be entirely satisfactory in its workings a specification must be sufficiently rigid so that any material which is unsatisfactory for the purpose intended may be rejected under the specification, and yet sufficiently broad so that material required can be secured without undue cost or delay. Good results have been obtained by drawing a tentative specification, using all the knowledge which may be available from previous tests on the material and similar specifications in general use (when such are obtainable), and keeping in mind the requirements which the material must fulfill to be satisfactory. These tentative specifications are then sent to manufacturers or dealers from whom the material may be obtained, with a query as to whether they can comply with the specification as written or what modification would enable them to furnish the material more promptly or cheaply, also whether the tests outlined are acceptable, and whether or not the specification as already drawn or as modified by their suggestions will apply to commercial brands of material on the market. A commercial product should always be aimed at in such specifications rather than a special product, which invariably costs more.

In certain cases, however, it may be necessary, on account of the use to which a material is to be put, to include requirements which are not usually considered commercial, as, for example, a requirement governing the resistance of steel strip when it is to be used in rheostat construction. In the make-up of specifications for materials entering into electrical apparatus, it is found that such specifications refer mainly to mechanical dimensions and chemical and physical characteristics rather than electrical characteristics.

Occasionally a preliminary specification is accepted without objection, but more frequently changes or additions are suggested, after which there follows a process of adjustment by means of which the various interests are made to agree, as far as possible, in regard to specific characteristics and tests which will admit material from the greatest number of available sources and which will also maintain a standard of quality satisfactory to the user. Before such a specification is finally adopted, it is necessary that all parties interested in it be consulted. The purchasing agent may desire to include something in regard to the basis on which unsatisfactory material may be rejected; the storekeeper may be interested in the size of the package and how it shall be marked; or the superintendent may wish to insert a clause that will lessen the labor in handling the

material in the shop. The final copy, including all the suggested changes and additions it is thought advisable to incorporate in the specification, is then sent to the manufacturers or dealers for their final approval. Experience has demonstrated that frequent consultation with those who are to supply the material is very advantageous, as it promotes a better understanding of the situation on the part of all concerned and avoids much of the friction that would otherwise occur in regard to the acceptance of shipments. If the purchasing company issues its specifications without such consultation, a misunderstanding of their intent may cause the sellers to either increase their price or even refuse to compete for the business.

Although a specification may have been adopted and put into operation, it cannot be called completed until after a considerable period of time has elapsed. Attention has previously * been called to the fact that the maker of a specification for a material that has previously been bought without specification may consider himself rather fortunate if the specification does not need to be revised in some six or ten months after it has been issued. One of the reasons for the necessity of revision is that, while it is very easy to write a specification which can be understood, *it is very difficult to so word a specification that it cannot be misunderstood,* and the writers of specifications are sometimes astonished to find how many meanings can be placed on a phrase or sentence which they had believed to contain but one meaning. It also sometimes occurs that a small detail which was considered satisfactory when the specification was drawn will prove to be quite unsatisfactory in practice. A specification recently drawn up for round steel bars stipulated that the heat numbers and maker's initials should be stamped at one end of the bar. This provision met with no objection in the preliminary stages either from the manufacturers of the material or from those interested in its use in the factory. After the specification had been in force for some time the men in the shop complained that great difficulty was experienced in locating the numbers on the bars in large piles because the stamping, while done at the end of the bar as specified, was on the cylindrical surface. A change in the specification which required that the marking be placed on the flat surface of one end of each bar, removed this difficulty. This was relatively of small importance, but neglect to make the change would have caused a great deal of inconvenience and unnecessary labor. The

*In a paper by Dr. Dudley before the American Society for Testing Materials.

case is illustrative of the unforeseen ways in which a specification may fail to give complete satisfaction, and it also shows why considerable time is required for seasoning in the preparation of a good working specification. This case is also illustrative of the difficulty of expressing a simple statement in a way which cannot be misunderstood.

There is a third class consisting of those materials which can only be partially covered by a specification. These materials are of such nature, or the conditions surrounding their use are such, that, with any tests practical enough to adopt in a specification, it is not certain that material conforming to the specification will be satisfactory in service. On the other hand, practical tests may be known such that non-compliance with them will conclusively prove that the material is unsatisfactory, so that a specification based on such tests has a certain value in a negative way. These materials are best handled under a combination system of approved brands and specifications in which the sellers of the materials guarantee them to meet the prescribed tests, and the purchaser buys only those brands that have been found satisfactory in his business.

Copies of purchasing department specifications are given to inspectors of raw material for their guidance in accepting or rejecting shipments. Every specification should contain a clause giving the company the right to reject any material which does not conform to any and every requirement in the specification, but many specifications cover points which, while deserving consideration, are not always of primary importance, as, for example, the size of packages, the method of packing and marking, and sometimes also the shapes and sizes of the material itself.

There may be other requirements in the purchasing department specification, non-compliance with which would unfavorably affect the cost of production in the factory, but would in no way affect the completed apparatus. In this case the inspection specification should require the inspector to reject a shipment only when there is a sufficient amount of the material in the storeroom to supply all needs until another shipment can be received.

A rigid inspection of a large quantity of raw material causes considerable expense and as certain classes of defects in some materials will appear, if they exist, when the material is handled in the factory, it is sometimes advisable to omit inspection when the material is received. To permit this, the purchasing department specifications must be so drawn as to admit of returning the material for

credit whenever defects appear. As an illustrative case, consider the quality of hardness in magnet wire. This quality is not detrimental to completed apparatus but it is very obectionable to the winders and, as they are certain to discover it, the inspectors need not be required to examine each reel for hardness.

### SAMPLES

Another feature of the raw material supply which should be considered is that of samples of materials which the producers submit for investigation in the hope of securing new business. The number of such samples coming to the writers' attention in the course of a year is some thousands. These cover almost every class of raw material, hardware, manufacturing supplies, etc., and the labor and expense involved if all were tested as desired by those furnishing the materials would be very considerable. Many of the letters accompanying such samples are merely to the effect that the sample is submitted for test and no information is given regarding the characteristics of the material submitted, and there is apparently no knowledge on the part of the producer of the material as to whether it would meet any of the requirements of this general class of materials as used by the company to which it is submitted. Other letters frequently convey no idea of the application of the material, simply stating that it is meeting with universal favor, and, this being the case, they assume that there is no reason why it should not be immediately purchased in large quantities by the manufacturing company. Samples are frequently of mailing size, and often quite insufficient for satisfactory tests. Even the name applied to some of these materials is frequently so designed as to afford no clue to its proper classification. This is especially true of the new grades of insulating materials, which are sometimes designated by proprietary trade names. The number of new materials brought out during the past few years in this line has apparently been so great and the name-makers have been so crowded that a list of some of these names would sound like the reading of a telegraphic code.

The manufacturing company necessarily derives great benefit from testing and investigating the samples which it receives; many of them give valuable information and start investigations that lead up to the adoption of a material possessing superior qualities or economical advantages. It is probably not desirable to have the number of such samples diminished, but it is very desirable to have each sample accompanied by all information bearing on its charac-

teristics, uses, etc., which the sender can obtain. This information should cover not only the commercial points of prices, deliveries, etc., but also the name of the class of materials to which the sample belongs, its most prominent characteristics, and the principal uses to which the material has been put, also specifying the results of tests—physical, chemical or electrical—to which the material has already been submitted. Such information would often enable immediate decision to be made as to whether a material is worth investigating or whether it has any application in the work of the manufacturing company, while the lack of such information sometimes results in the rejection of a valuable material after preliminary tests to determine its suitability for a purpose for which it was never intended.

To get the full benefit that may be derived from handling and testing a large variety of materials, it is very desirable to have a clean, well-lighted room fitted up with shelves, cases, bottles, etc., in which samples, properly labeled, may be filed in numerical order. An alphabetical card index should be kept of the samples, each card bearing the serial number, history, characteristics, results of tests, and any special information of interest in connection with a sample. The collection should include new materials having valuable characteristics, standard materials regularly used in production, and samples illustrative of undesirable characteristics that have caused failures in regular service.

Such an exhibit gives engineers and draftsmen, at any time, a convenient opportunity to see the materials they are required to specify and to learn their characteristics. It prevents waste of labor caused by unnecessary duplication of tests as, in the course of a year or two, attention may be asked for several different samples of the same or similar material not readily recognized as such. A comparison of new samples with the permanent exhibit would frequently show such striking similarity to samples previously tested and rejected as to clearly indicate the futility of making tests on the sample in hand.

In the case of materials bought on "approved brands", without specification, it is especially desirable to have on file a sample of the shipment that was originally tested and approved, to serve as a standard for comparing with future shipments; and in the case of materials bought wholly on specification some well mounted samples, of material which is known to comply with the specification, are useful in showing representatives of new firms the appearance of the material wanted.

# NEUTRAL CURRENTS OF A THREE-PHASE GROUNDED SYSTEM

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THE very interesting article on "Circulating Currents in Three-Phase Generators", which appeared in the April issue of the JOURNAL, deals principally with the circulating currents in delta machines, which are caused by the third harmonics in the e.m.f. wave. There are, however, possibilities of very considerable and even dangerous idle currents in generating systems, consisting of several star-connected generators, with their neutrals grounded, even though the load be delta-connected.

If two such generators are exactly similar in characteristics and are operated under precisely the same conditions as to instantaneous speed, load, and excitation, there will be no possibility of circulating currents either in the bus-bars or in the neutral connections, for the generated e.m.f.'s in such a case would be exactly equal and opposite, both in the fundamental and higher harmonics. If, however, the similarity of the two generators is not exact, i. e., if there is any phase displacement, change of magnitude, or frequency of one of the generated e.m.f. waves, there will be a resultant differential potential, which must produce circulating currents. As explained in the paper above mentioned, the interchanged current consisting of the fundamental and harmonics, not multiples of three, passes through the bus-bar connections, and that made up of the triple harmonics, passes through the bus-bar connections and neutrals in series. The phase displacement and variation in magnitude of the generated e.m.f. waves may be produced by several causes, viz.: a change in excitation, a momentary fluctuation of angular velocity, or a permanent change in driving torque of one or more machines. Each of these causes will produce a variation in the magnitude and a phase displacement of the generated potential waves, as can be seen from a consideration of the ordinary vector diagrams for alternators.

The variation in magnitude of the e.m.f. wave will produce a resultant differential voltage, similar in wave form to the generated e.m.f. The phase displacement will produce a resultant of different

wave form, in which the higher harmonics are exaggerated in magnitude.*

The momentary variations of angular velocity above mentioned will also produce differences in amplitude and frequency of the generated e.m.f.'s. The resulting differential potential will have a wave form not sinusoidal, and with a frequency slightly different from that of the load currents. The interchange of current produced by this component of the voltage will flow through the bus-bars as it is not a triple harmonic.

It is evident from the foregoing discussion that the presence of even very weak triple harmonics in the coil wave forms of *Y*-wound generators operated in parallel with their neutrals grounded, may cause circulating currents in the neutral connection, if the machines are not properly adjusted as to excitation and load, and the prime movers do not deliver uniform driving torques.

When the high tension generating system of the Interborough Rapid Transit Company of New York City was first grounded, the neutrals were connected together without resistance to a common neutral bus-bar, which was grounded through a grid rheostat of about six ohms resistance. A current transformer on each of these neutral connections controlled a relay on the main generator switch. The generators are 25 cycle, *Y*-wound machines with 40 poles and a capacity of 5 000 kw at 11 000 volts. Each generator is driven by a double-compound engine, each half of which consists of a horizontal high pressure, and a vertical low pressure cylinder, both connecting rods being connected to a single crank pin. The crank angle of the two halves is 135 degrees.

From the first, trouble was experienced, as mentioned by Mr. C. W. Ricker, in an article on "Experience with a Grounded Neutral

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*Let $\theta$ = the phase displacement,

$i_0$ = interchange current,

$E_1$, $E_3$, $E_5$ — maximum values of 1st, 3rd, 5th — harmonics.

$$i_0 = K\left[E_1 \sin\frac{\theta}{2}\sin pt + E_3 \sin\frac{3\theta}{2}\sin(3pt + a_3) + E_5 \sin\frac{5\theta}{2}\sin(5pt + a_5)\ \ldots\ldots\ldots\right]$$

If $\theta$ be small, as is usually the case,

$$i_0 = K\left[E_1\frac{\theta}{2}\sin pt + E_3\frac{3\theta}{2}\sin(3pt + a_3) + E_5\frac{5\theta}{2}\sin(5pt + a_5)\ \ldots\ldots\ldots\right]$$

in a High Tension Plant", which appeared in the JOURNAL, in September, 1906. Briefly, it was as follows:

With four or more generators operating in parallel, there were large, widely fluctuating currents in the neutral connections, at times greatly exceeding half the full-load current. When a new machine was synchronized, with its neutral grounded, it was very difficult to keep it on the line, the neutral current tripping the main switch as soon as it was closed. These neutral currents could be reduced to a

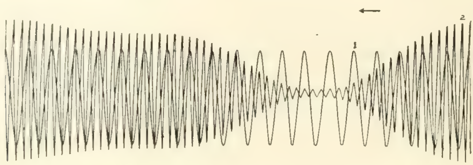


FIG. 1—EFFECT OF FLUCTUATIONS IN DRIVING TORQUE

Curve *1* shows curve of potential between phases. Curve *2* shows the variations in the neutral current.

certain extent by careful adjustment of excitation, and by the introduction of resistances in the neutral connections. Such resistances were too bulky to be considered, and a solution of the difficulty

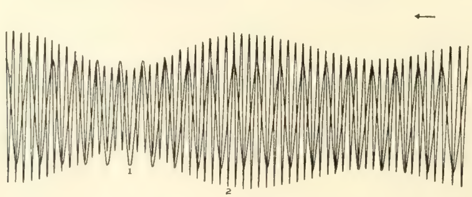


FIG. 2—COMBINED EFFECT OF FLUCTUATIONS IN DRIVING TORQUE AND EXCITATION

Curve *1*, potential between phases. Curve *2*, neutral current.

was found in grounding the neutral of only a single generator at a time.

With the sixty cycle turbo-alternators on the Subway lighting system, no trouble was experienced, although there were neutral currents when connecting a machine to the line, and such currents would be produced by variation in excitation.

An oscillographic study of the circulating currents in the Inter-

borough generators was made by Mr. G. F. Chellis. For this purpose, a generator was driven with one side of the engine idle, to increase the fluctuations of angular velocity. The neutral of this generator and an adjacent one were connected without resistance to the grounded neutral bus. All other generators were operated with their neutral switches open. Under these conditions, a series of records was taken, some of which are here shown. In all of the

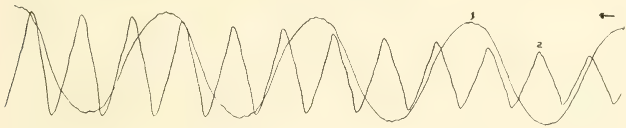


FIG. 3—CURVES TAKEN UNDER CONDITIONS SIMILAR TO THOSE OF FIG. 1, BUT ON AN EXTENDED SCALE

Curve *1* represents potential waves of coil voltage and curve 2, neutral current. The higher harmonics are quite evident.

records, the arrow indicates the direction of motion of the film under exposure. The curves are not to the same scale.

Figs. 1 and 2 show the effect of fluctuations in the driving torque. The relative phase relations and frequency of the potential between phases (Curve 1) and the neutral current (Curve 2) are shown. The triple frequency of the neutral current is strikingly clear, none of the fundamental being present. There was a cyclic variation in its magnitude, covering twenty complete e.m.f. waves, with a smaller

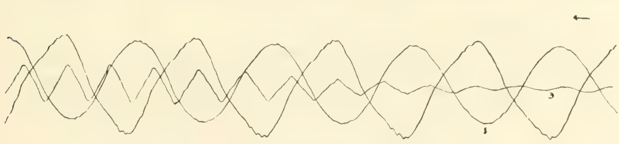


FIG. 4—CURVES TAKEN UNDER CONDITIONS SIMILAR TO THOSE OF FIG. 1

Curve *1* represents coil voltage; curve *2*, current (reversed) in same coil, and curve *3*, neutral current. The characteristics are similar to those of the curves in Fig. 3.

variation every ten cycles. In view of the number of poles (forty) it is at once apparent that this fluctuation in magnitude of the neutral current is due to the non-uniformity in angular velocity of the prime movers. In Fig. 1, the neutral is practically zero at one point, while in Fig. 2, such is not the case, showing that when one record was taken the current was produced by fluctuating speed alone, while when Fig. 2 was taken, unequal excitations had a part.

In Figs. 3 and 4, which were taken under similar conditions,

the wave forms are shown to a more extended scale. The presence of the higher harmonics in all of the curves is quite evident. In Fig. 3, potential waves of coil voltage (Curve 1) and neutral current (Curve 2) are shown. The very high harmonics in the potential wave are probably due to the armature slots, there being four slots per pole per phase. The presence of the third harmonic in the

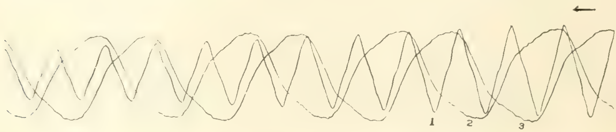


FIG. 5—CURVE SHOWING THAT THE THIRD HARMONICS ARE IN PHASE WITH EACH OTHER

Curve *1* represents neutral current; curves *2* and *3*, currents in two coils.

coil potential wave is quite apparent from the flattening of the latter portion of the half wave. The neutral current indicates a marked third and even higher harmonics, these being no doubt exaggerated by the charging current of the system, which consists of about 300 miles of No. 000, 3-conductor cable. Fig. 4, which shows coil voltage (Curve 1), current (reversed) in the same coil (Curve 2), and neutral current (Curve 3) has the same characteristics as Fig. 3.

Fig. 5 shows that the third harmonics in the wave forms of the

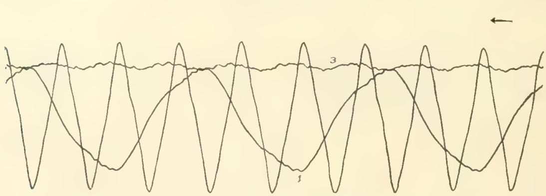


FIG. 6—SHOWING EFFECT OF NEUTRAL CURRENTS ON THE EXCITING CURRENT

Curve *1* represents coil potential; curve *2*, neutral current, and curve *3*, field current.

different coils are in phase with each other, Curve 1 being the neutral current, and Curves 2 and 3 being the currents in two of the coils.

Fig. 6 shows the effect of the neutral currents on the exciting current. Curve 1 shows coil potential, Curve 2, neutral current,

and Curve 3, field current. The less frequent fluctuations in excitation are seen to be of the same frequency as the neutral current, while the more rapid variations are evidently due to the slots, twelve per pole. There is no fluctuation in the field current corresponding to the fundamental frequency, as the reaction caused by the sinusoidal load current is stationary with respect to the field, but the

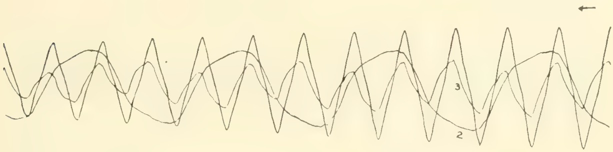


FIG. 7—CURVES SHOWING RELATIONS OF NEUTRAL, COIL AND BUS-BAR CURRENTS

Curve *1* represents neutral current; curve *2*, coil current; curve *3*, bus-bar current. The bus-bar current was measured by the drop along the bus-bar between the two generators.

higher harmonics in the current produce fields rotating with respect to the main field. These rotating magneto-motive forces cause a transformer action in the field coils, and produce fluctuations in field current of corresponding frequency.

Figs. 7 and 8 show the neutral current (Curve 1), the coil current (Curve 2) and the bus-bar current (Curve 3). The bus-bar current was measured by the differential voltage between the corresponding terminals of the potential transformers of the two generators, this potential being in effect the drop along the bus-bars between the two generators. It may be seen that the bus current thus measured has a wave form consisting of a very weak fundamental, with a predominating third harmonic.

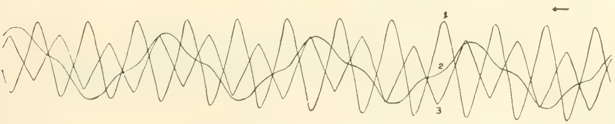


FIG. 8—SIMILAR TO FIG. 7

Curve *1* represents neutral current; curve *2*, coil current; curve *3*, bus-bar current. The strong third harmonic is quite evident.

Figs. 9 and 10 are similar to Figs. 7 and 8. A careful exami-

nation of the curves shows that the fundamental frequency of the bus-bar current (Curve 2) is not quite the same as that of the po-

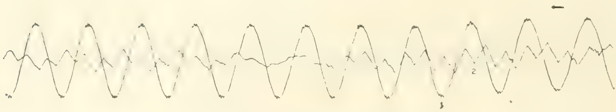


FIG. 9—SHOWING SLIGHT DIFFERENCE IN FREQUENCY OF BUS-BAR CURRENT AND POTENTIAL BETWEEN PHASES

Curve *1* represents potential between phases; curve *2*, bus-bar current. The difference in frequency is probably due to speed fluctuations in the prime movers.

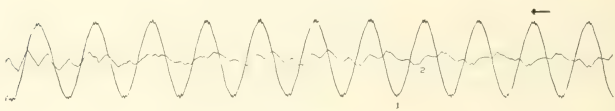


FIG. 10—SIMILAR TO FIG. 9

Curve *1* represents potential between phases; curve *2*, bus-bar current.

tential between phases (Curve 1), the difference being no doubt due to the speed fluctuations of the prime movers.

# RAILWAY SIGNALING—V

## AUTOMATIC BLOCK SIGNALING

### GENERAL

W. E. FOSTER

GIVEN a section of railroad from which large earnings are to be derived and assuming that there is plenty of business to handle, the problem is to move the maximum number of trains over it with economy and safety. If every train had a track of its own, no block system would be necessary, but on the leading railroad systems the traffic has increased much faster than the trackage. One of the most helpful and efficient means for safely handling a large number of trains over the same track is a good block system.

### DEFINITIONS AND CLASSIFICATIONS

Before enlarging upon this subject, a few definitions may be of value to the reader.

A block is a length of track of defined limits, the use of which by trains is controlled by fixed signals.

A block signal is a fixed signal controlling the use of a block. The word "fixed" refers to location only since block signals are movable signals in fixed locations.

Block signals may be classified in three ways:

1st—As to the manner in which their day indications are displayed.

2d—As to the manner in which they are controlled and operated.

3d—As to what they control.

Under the first classification there are:

(a) Banner signals, the indications being displayed by a revolving banner.

(b) Disc signals, the indications being displayed by a movable disc in front of a fixed background; and

(c) Semaphore signals, the indications being displayed by the position of an arm moving in a plane at right angles to the track. In all types under class *one* the night indications are displayed by colored lights.

Under the second classification there are:

(a) Manual, the signal being controlled and operated by man

power. (b) Controlled manual, the signal being operated manually and constructed so as to require the co-operation of the signalmen at both ends of the block. (c) Automatic, the signal being operated by power which is controlled entirely by the presence or absence of a train in the block, or the condition of the track.

Under the third classification there are:

(a) Home block signal, a fixed signal at the entrance of a block to control trains in entering and using said block.

(b) Distant block signal, a fixed signal used in connection with a home block signal to regulate the approach thereto. The indications displayed by a home signal are "stop" and "proceed", or in some cases "stop", "caution" and "proceed".

An absolute block system is one which never allows more than one train in the same block at the same time.

A permissive block system is one which may allow more than one train in the same block at the same time, provided the trains are going the same direction and the second train has been warned by signal that another train is in the block.

### EARLY BLOCK SYSTEMS

The older block systems in this country were all manual or manual controlled, following the practice in England and Germany. The enormous increases in the amount of traffic to be handled with only slight increases in trackage, together with the fallibility of the signalmen operating the signals, led to the development and use of automatic block signals. Briefly, both economy and safety led to this development. In the days when the station agent was ticket agent, baggage man, freight agent, freight handler, telegraph operator, etc., it was thought that to let him also handle the manual block signals would be good for him while he was resting. As traffic increased, these various duties became more and more onerous, the stations were not close enough together to be serviceable as block stations, and the men became too busy to handle the signals reliably.

The next move was to install block stations in the outlying districts. This meant a first cost of about $1 000 for the station and signals, and a yearly wage cost of not less than $1 000 to $1 500 for each block station. Furthermore, the men still made mistakes and gave wrong signals.

### AUTOMATIC BLOCK SIGNALS

The automatic block signal must be a permissive signal in order that, if a signal is out of order and assumes the stop position, traffic

may not be entirely suspended for several hours. On double track lines this is not serious, as a train, after stopping at a signal out of order, may proceed with caution through the block expecting that another train is already ahead of it in the block, that a switch is misplaced or that a rail is broken. On single track lines it was thought that the delays might become serious, since when a train receives a stop signal it is necessary to protect it by sending a flagman ahead through the block. For this reason automatic blocking on single track has not met with general favor. The only two single track lines using this system extensively are the C. N. O. & T. P. Ry. and the Harriman Lines, the latter having installed several thousand automatic signals on single track. The Harriman Lines already claim to have shown that the expense of the system was warranted on account of the numerous cases of broken rails which have been reported by the automatic signals.

It is the purpose of this article to describe only the arrangements of signals in common use on double track lines and the automatic electric semaphore signal which is in most general use.

### LENGTH OF BLOCKS

The ideal arrangement of automatic signals to secure the maximum capacity for train movements over a given piece of track would be to first decide upon the maximum distance required for stopping any train on the road. This can be decided from the air brake tests, and this distance would have to be the minimum length of the block. Since it is more difficult to stop on a descending grade and less difficult to stop on an ascending grade, the blocks would gradually be lengthened out on the descending grade and gradually shortened on ascending grades. As large terminals are approached the blocks would gradually be shortened on account of the limited speed of trains and congestion of traffic at such places. Having fixed the locations, the control of the signals should be such as not only to warn an engineman when he reaches a block which is occupied, but also to warn him in time to permit him to stop his train before reaching the entrance of the occupied block. With this arrangement and control of signals it would be possible to start two trains from one end of the line two blocks apart, run them the length of the road at the same speed and have them arrive at the other end still just two blocks apart. The second train would receive clear signals all the way; or if the first train should stop at any point, the second would receive due warning and would have plenty of space

to stop in before reaching the block which was occupied by the first train.

In ordinary practice to-day the minimum length of block is seldom used, and the length commonly varies from 4 000 feet to 12 000 feet. Frequently so little heed is paid to the principles mentioned above that the ideal arrangement is far from being reached. One of the principal reasons for improper spacing is that if a signal is located in its proper place for uniform spacing of trains, it cannot be readily seen on account of the curvature of the line or obstructions to the view, such as bridges. All of the diagrams of signal arrangement in Figs. 1 to 5 show the home signals as arms with square ends and the distant signals as arms with forked ends. In every case the block is the space between home signals, the distant signals being nothing more than repeaters for the home signals.

### SEMAPHORES ON SEPARATE POSTS

Fig. 1 illustrates the arrangement of signals in an automatic block system using semaphore home and distant signals mounted on

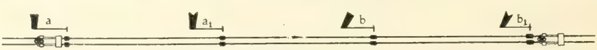


FIG. 1

separate posts. This arrangement is used very little excepting where traffic is light and the home block signals are considerably more than one mile apart. The distant signals would probably be located not more than 4 000 feet from their respective home signals.

A home signal is shown at *a* in the stop position with a train just past it in the block. The arm is horizontal and a red light would be displayed at night. It means "stop and wait the prescribed time (usually 1 minute) then proceed under control expecting to find a train in the block, a misplaced switch or a broken rail." The distant signal for *a* is shown at $a_1$ and is in the "caution" position. Some roads use a green light for the night indication; others use a yellow light instead. It means "expect to find next home signal in the stop position." *b* is a home signal in the proceed position. The arm is inclined at an angle of 60 or 75 degrees from the horizontal. On roads using green for "caution" a white light would be displayed at night. On roads using yellow for "caution" a green light would be displayed at night. It means "proceed, the block is unoccupied, all switches are set right and rails are unbroken." $b_1$

is the distant signal for *b* and is in the proceed position. On roads using green for "caution" a white light would be displayed at night. On roads using yellow for "caution" a green light would be displayed at night. It means "proceed, expect to find the next home signal in the proceed position."

Using this arrangement, trains can run at speed if spaced a distance equal to one block (*a* to *b*) plus the distance between a home

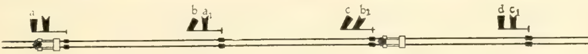

FIG. 2

signal and its distant ($b$ to $b_1$) or ordinarily about 10 000 feet + 4 000 feet = 14 000 feet apart.

On most roads the blocks do not often exceed 7 500 feet in length and it has been found convenient as well as economical to use the arrangement shown in Fig. 2 which shows home and distant signals mounted on the same post.

SEMAPHORES ON SAME POST

The indications and meanings of the signals shown in Fig. 2 are identical with those described in Fig. 1. It is developed by shortening the length of blocks *a b* in Fig. 1 until $a_1$ and $b$ are so close together that it is best to mount them on the same post. With

FIG. 3

this arrangement trains running at speed would be spaced two blocks apart, although the actual distance might be the same or less than that shown in Fig. 1.

THREE POSITION SIGNALS

Fig. 3 illustrates the arrangement and use of three position signals. Each signal is a home signal and distant signal combined. *a* is a home signal in the "stop" position. The arm is horizontal. The meaning is the same as *a* in Fig. 2. The night indication is the same as *a* in Fig. 1. *b* is a home signal in the "caution" position. The arm is inclined at an angle of 45 degrees from the horizontal. The meaning is the same as $ba_1$ in Fig. 2. The night indication is the same as $a_1$, Fig. 1. *c* is a home signal in the "proceed" position. The arm is inclined at an angle of 90 degrees from the horizontal.

The meaning is the same as $cb_1$, Fig. 2. The night indication is the same as $b$, Fig. 1.

The semaphore signal is primarily a position signal, yet in Figs. 1 and 2, both arms $a$ and $a_1$ are in the horizontal position but have two entirely different meanings. The signals shown in Fig. 3 are


FIG. 4

theoretically more correct in this respect. Both schemes are extensively used, both have arguments in their favor, and both have many ardent advocates. As far as the spacing of trains is concerned, Figs. 1 and 2 are exact equivalents.

## OVERLAP SYSTEMS

*Partial block length*—An "overlap" system, as shown in Fig. 4, is one in which each home block signal is so controlled that it will remain in the stop position until the train has passed a certain prescribed point in advance of the next home signal. It has been used in arrangements like Fig. 1 but presupposes that conditions may arise which may cause an engineman to run by a home signal in the stop position without making the stop and gives him additional space to stop in. It is very questionable as to whether it should be used except in unusual cases where the blocks are, on account of traffic,


FIG. 5

very short and it is doubtful as to whether a train can stop in the length of one block only. This system is open to the objection that, if an engineman knows that there are at times two stop signals between him and the preceding train, he may assume that there are always two stop signals between and run by the first without attempting to stop.

If, as in some of the earliest installations, home signals only are used, the overlap is necessary because in many cases local conditions will not permit the location of signals so that they are visible a safe stopping distance away. The distant signal takes the place of the overlap except where the blocks are extremely short. With the arrangement shown in Fig. 4 trains would be spaced two and one-half blocks apart.

*Full block length*—Another overlap system is shown in Fig. 5 which differs from Fig. 4 in that the overlap is a full block in length. With this arrangement trains would be spaced three blocks apart. This system is used in the New York Subway. There the blocks are only 800 feet long and there is a full block overlap and each signal has an automatic train stop working in conjunction with it.

In the foregoing description the spacing of trains refers to their spacing if they are running at speed past all signals in the proceed position. In Figs. 1 to 4 the second train would not have to actually stop until it reached the signal *a*. In Fig. 5 the second train would not have to stop until it reached the signal *b*.

## CONSTRUCTION

*Counterweights*—All automatic signals must be so constructed that the weight of all moving parts tends to restore the signal to the stop position. To secure this with all of the signals illustrated the semaphore arm has to be counterweighted. The counterweight must be sufficient to carry the arm to "stop" even when it is covered with snow and ice.

It is plain that, if the arm traveled in a quadrant above the horizontal, little counterweight would be necessary and the arrangement would be safer and more economical of power. Recently signals having arms working in the upper quadrant have been installed on the Pennsylvania railroad and the scheme is being urged on many other roads. In such an arrangement the meanings of the signals would correspond with the meanings of arms at equal angles in the lower quadrant.

If an automatic signal is so counterweighted that it will go to the "stop" position by the force of gravity, it is evident that it must be moved to the "proceed" position by the application of power and held there by power. Before going into the construction of the signals themselves it is well to see how a train in passing a signal in the proceed position cuts off the power so that gravity returns it to the "stop" position.

*The track circuit*—The track circuit is the foundation of every automatic block system. It is its main element of strength and it is also one of its weakest elements if we are to consider the many annoying troubles which arise from it. The track circuit was invented in 1872 and has been used in all kinds of signaling and protective schemes. The installation of a section of track circuit is very sim-

ple. It merely means the removal of one of the iron fish plate joints from each rail at each end of the section and replacing them with one of the many types of insulated joints; the bonding together of the intermediate rails by running bonds of No. 8 galvanized iron wire around each joint and connecting a battery across the rails at one end and an electro-magnet across the rails at the other end. From the diagram in Fig. 6 it may be seen that this would form a closed circuit, the rails simply connecting the battery to the electro-magnet. This electro-magnet is called a relay. It has a pivoted armature weighted so that it will fall away from the cores by gravity and the magnet must be energized to raise it. The moving armature carries moving contacts for controlling auxiliary electric circuits and is used to control the operating circuit for a signal. The wheels of the train when on the track circuit offer so little resistance to the current that the relay does not get enough current to

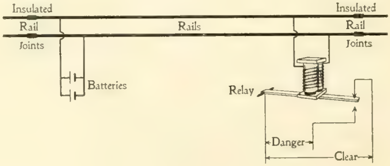


FIG. 6

hold the armature up. It then falls and opens the signal operating circuit.

While the track circuit is fundamentally very simple it has been very difficult to make the arrangement operate under all conditions for the following reasons:

1st—There is no insulation between rails except the ties and ballast and during wet weather the leakage between rails is considerable.

2nd—The source of current is usually a gravity battery, although in recent installations some storage batteries are used. The voltage and current capacity in the case of the gravity battery are low and the problem is to arrange the cells so as to furnish enough current to feed the leakage between rails and also feed the relay enough current to operate it satisfactorily in wet weather.

The actual figures in regard to the amount of power used to operate one track circuit seem ridiculously small to an electrical engineer. For instance, the total amount of energy expended for one

track section is seldom more than one-half of a watt. The amount needed to operate the relay is less than one-fourth of a watt. Yet it is a difficul task to hang on to that one-half watt through from 2 000 to 5 000 feet of track with low insulation between rails.

The voltage used is ordinarily from one to two volts. If the voltage is increased much above this the leakage is so excessive that the gain at the relays is very little. If the resistance of the relay is much above nine ohms the relay will not work in wet weather. If the resistance is much below four ohms the train will not cause it to open.

The energy expended is divided in some such way as this:

Ten percent is used to overcome resistance of rails and connections to battery and relay.

Sixty percent is lost by leakage.

Forty percent is used in operating the relay.

3rd—The relay must be inclosed and sealed so that careless maintainers cannot adjust or tamper with it, and moisture cannot get on the contacts moved by the armature and freeze them closed. It must be protected by high grade insulation in all its parts so that lightning cannot fuse its contacts, and must also be protected by a first class lightning arrester.

The various arrangements of track circuits and signal control circuits will be treated in the following article.

# SALES CONTRACTS—II

## KINDS OF SALES CONTRACTS

B. A. BRENNAN

Contract Manager, Westinghouse Machine Company

CONTRACTS from the standpoint of sales, particularly those of machinery, are classified as:

*Simple Sales Contracts;*

*Conditional Sales;*

*Bailments and Consignments.*

### SIMPLE SALES CONTRACTS

Simple Sales Contracts are those simply covering the sale of machinery or product at a specific price and with agreed terms of payment.

A Sales Contract may be defined as a mutual assent by competent parties to the transfer of property for a determined consideration to be paid therefor.

A sale or bargain, when reduced to its simplest elements, is found to consist of a proposal or offer made on one side and accepted on the other. The proposal as made ought to be distinct and clear, and its acceptance should be correspondingly clear, full and unequivocal. If the acceptance falls short of the offer, or seeks to expand it, the negotiation may continue, but there is yet no mutual assent and no bargain. All bargains, to be complete, must be mutual and reciprocal; both parties must be bound; not one alone. A contract is always faulty from a practical sense, or that of easy consummation, which permits of diverse interpretations or does not stand out as an instrument specific in its terms and conveying no doubt as to the exact intention of the parties to it.

*Price*—In a Sales Contract, price is an element which must be determined, or is determinable. Immediate payment need not be made, but there must be an agreement to pay. In the absence of a fixed or specified price the law will imply a promise to pay as much as the property is reasonably worth.

### CONDITIONAL SALES

A Conditional Sale might be termed a sale under which the title and right of possession to the material or machinery sold shall remain in and be vested in the seller until the full purchase price shall

have been made in cash, or until some other condition mentioned in the sale shall have been performed.

That there must be some condition to be performed before actual transfer of title, and that the condition must be complied with, or waived, before title passes, is well established law, and the condition may be one to be performed either before or after delivery. This condition may be dependent for fulfillment either on the seller or user, and may refer to the articles which are contained in the contract or to the consideration to be paid therefor.

Machinery manufacturers or dealers in articles of manufacture have many occasions to make delivery of goods under contracts providing for future payment, and it is often desirable, from the standpoint of credit security, to retain the title to the machinery until payment has been fully made in cash. Dealers usually resort to contracts of conditional sale and sometimes bailment; however, almost invariably using indiscriminate and standard forms of contract without particular regard to the laws or statutory provisions of the particular states to which the material is delivered, or without regard to any procedure subsequent to the execution of the contract tending towards the preservation of the security intended to be given or derived under this feature of the agreement.

In the consideration of such sales a great deal of discretion and discrimination is necessary, because, while as between the parties the validity of such sales is unquestioned, and in many states the rule applies in the same manner to third parties without notice or record, since in the absence of state laws or statutes requiring the filing or recording, the general rule is that the vendee (or customer) under a conditional sale obtains no title to the property before sale as would render the property subject to attack by his creditors, nor can he convey title to bona fide purchasers that can be enforced against the original seller. There are, however, many exceptions to this rule, and the laws of the different states are extremely varied in this respect.

In nearly every state all conditional sales are valid as between privy or direct parties; that is to say the customer and seller, without any record; but in many states all conditional sales, or sales where title is to depend upon any condition, must, to be valid as against third parties, be filed or recorded after procedure prescribed by statute. In each instance the filing or the recording of the terms of sale must be in the town or township where the vendee resides and the property is located, except in some few states where, if the

customer is not a resident of the state, the filing or recording may be done where the vendor resides. In a few states the record shall not extend beyond one year unless it is renewed from time to time.

As to foreclosure or exercising vendor's rights under such contracts, few states have prescribed the mode of procedure. In some states the vendor may retake the property thirty (30) days after the condition is broken, while in other states the property is subject to redemption by the customer unless otherwise stipulated in the contract.

The question has been asked whether a contract reserving title, with right of possession to the manufacturer, and where prior to shipment a trust deed to secure a bond issue was given stipulating that it covered all the property, both real and personal, which the customer then owns or may thereafter own, would prevail against the deed. On this question the authorities are not by any means harmonious. In Indiana, for instance, it does not seem that the Supreme Court has ever passed on the question directly, and there is no statute in said state which covers conditional sales or requires them to be executed or recorded in any particular manner. Such sales, however, have always been held valid by the courts of Indiana in a long line of decisions. These decisions are to the effect that where personal property is sold under a conditional sales contract, the title to remain in the vendor until payment in full of the purchase price has been made, that the title does not pass to the vendee until a full performance of the conditions, and neither he, nor his purchaser claiming under him, nor bona fide creditors can claim the property as against the rights of the seller; that a vendee in such conditional sales acquires no interest which is subject to lien and sale of third parties, and that such vendee can do nothing which will in any manner affect the rights of the vendor thereunder.

Such sales being thus recognized as valid against subsequent purchasers, the question next arises whether, considering the machinery in question personal property, it would pass under the previously executed trust deed or mortgage covering all of the property which the Company owned at the time of the execution of the trust deed or might thereafter acquire. This has been passed upon in the United States courts and other courts. In one case a railroad company executed a mortgage, and bonds were issued thereunder. The mortgage covered all the property the railroad company then owned or possessed, or might thereafter acquire either in law or in equity. Subsequently, a seller delivered to it under a conditional sales con-

tract, a number of coal cars. The bond holders subsequently filed a bill to foreclose the mortgage, and it was claimed at the trial that the title to the cars had passed to the railroad company under a contract with the seller and that subsequently the lien of the mortgage had attached to the cars as after-acquired property; but the court held that the mortgagor was not in any sense the purchaser of such property and had acquired no title. From this and the other authorities it is safe to say that if the machinery which it is proposed to sell under conditional sales reserving title, could be considered as loose property, susceptible of ownership and separate lien, that prior trust deeds or mortgages executed by the customer would not attach to the machinery except in the nature and condition in which it is received by the seller; that is, subject to the prior rights of the seller under the contract.

It is held that if machinery sold under conditional sales becomes a fixture, it will become subject to the prior mortgage, and a difficulty arises in the question as to whether such machinery will become a fixture. The rule is that the determination of this question varies according to the relation and intention of the parties between whom it arises. By fixtures is meant such articles which in and by themselves, irrespective of annexation to land, are of a chattel or personal nature; but by reason of such annexation become a part of the land. The point of dffiiculty arises in determining whether such material has, by its installation, become a part of the irremovable fixtures. It has been said in many cases that the true criterion used by the authorities in the united application of several tests, as follows:

1st—The intention of the parties installing the machinery;

2nd—The use, adaptation or purpose of that part of the realty with which it is connected;

3rd—The real or constructive annexation of the articles in question to the realty.

There are many differences of opinion on the subject of conditional sales, in the decision of different jurisdiction and on the same question, but the weight of authority is in favor of the proposition that the title to the property will be good as against prior or subsequent mortgages; but a wise precaution would be for the seller or vendor to place upon the machinery sold a name plate, indicating that the property is his. In all cases, however, it would seem expedient where mortgages already exist on the property on which the machinery is to be installed to obtain from the mortgagee a release

or waiver so far as the machinery is concerned.

*Clauses reciting reservation of title*—In formulating contracts of conditional sale, a short clause reserving the title and as is used by many machinery manufacturers, reads:

"The title to the machinery or material furnished hereunder remains in the vendor until the full purchase price hereunder (including any modifications or extensions of payments, whether evidenced by notes or otherwise,) shall have been fully paid in cash, and the vendee is to do all acts necessary to perfect and maintain such retention of title in the vendor."

Another clause is often used in contracts to follow immediately the suggested preceding one, the purpose of which is to define the intention of the respective parties to the contract with regard to whether or not the machinery shall retain its personal character. It reads:

"It is understood that the machinery hereunder shall retain its personal character and shall not become a fixture by being placed in any building or in any manner whatsoever annexed to any land. Further, if said machinery is placed upon mortgaged premises, it shall be without prejudice to the retention of title thereto in the vendor as herein provided."

*Fire insurance*—It is considered that if title does not pass that some decision or distinction should be made as to the possible loss or damage to the machinery in case of fire, and the usual disposition of the question is covered by another clause, reading:

"Fire insurance in an amount sufficient to protect the interest of the vendor in the machinery or material sold is to be taken out and maintained by the vendee, and the policies of insurance are to be made payable to the vendor as his interest may appear at the time of loss. The vendee to assume all loss resulting from fire in the event of his not having effected such insurance."

## PATENT CLAUSES

Customers frequently take the position that machinery or devices may be subject to patent litigation involving them in a suit or suits, and insist on a protecting clause in the contract, by which the seller agrees to save the customer harmless against damages resulting from the customer's use of the patented article. In agreeing to such an arrangement care should be exercised in its wording, so that the seller may reserve to himself the conducting of the suits, and covering which the following is a suggested clause:

"We hereby agree to indemnify and save you harmless from and under any and all claims or suits for damages for infringement of any letters patent claimed by any person or persons relating to any part or portion of this machinery, provided you give us prompt and sufficient notice of said claim or suit and such information, assistance and power of attorney as may be necessary to answer to and defend such suits."

### TERMS OF PAYMENT

In the recitation of the terms of payment the all important consideration is that they be specific, as to the manufacturer a contract is always faulty which permits of diverse interpretation, and the greatest conceivable defect in expressing terms of payment would be to have them dependent upon the customer's mood, temperament and, perhaps, caprice. The employment of such expressions as "satisfactory operation," "when in successful operation," or, in fact, any contingency that would permit defining of terms contrary to the seller's intention or the spirit of the contract is dangerous, and oftentimes occasions delay in payment unwarrantably.

We are all familiar with the contract contingencies that delay the progress of the work. Other contractors may not have completed their work; the customer's plans may change, so that they are not in readiness for the machinery; and against all such possibilities the contract should stand as an instrument, specific in its terms and conveying no doubt as to the real intention of the parties at the time the contract was entered into. A way to most clearly define the intention in such cases would be to employ a clause, reading—

"If shipment, erection or starting of the machinery, or any part thereof, shall, when ready, be delayed on the vendee's account, it is understood that payment shall be due as though shipment had been made, erection completed and the machinery started."

*Deferred payments*—When deferred payments are agreed upon in contracts these sums should be evidenced by the customer's promissory notes, with interest at legal current rates, and it is advisable that such payment should date on shipment. A good way to express the arrangement would be in the use of a clause, next following the recitation of the terms, reading:

"The deferred portion of the purchase price shall be evidenced by the vendee's (......) promissory notes, dated on shipment of the apparatus, and payable at the times hereinbefore mentioned, with interest at the rate of (......) percent per annum."

It is also advisable, where the deferred portion of the price is to be divided into different amounts to use the further stipulation that:

"Failure to pay any one note when due, makes all notes due at once."

as if default be made in any one payment suit could be brought for the whole amount without the necessity of awaiting the maturity of the others.

*Notes*—A promissory note is a written promise to pay to a certain person, or to his order, or to bearer, at a certain time, a certain sum of money; and he who signs the notes is called the Maker or Promissor, and the other party is the Promisee or Payee.

*Form of Note*—The form of note most generally used by machinery manufacturers is the following:

PORTLAND, ORE., May 1st, 1906.

"$1,000.00.

Three months after date, I, John Doe, promise to pay to the order of John Brown one thousand dollars ($1,000.00), at his office in Chicago, Illinois, for value received, with interest at the rate of six percent (6%) per annum until paid. I also agree that if proceedings are commenced to collect this note by law, ten per cent (10%) shall be allowed to include in the judgment thereon as attorney's fee. The Makers and Endorsers thereof each hereby waive presentation for payment, notice of non-payment and notice of protest of this note.

*(Signed)* JOHN DOE."

There are, however, several points in connection with this form of note to which special attention is called.

*Amount of interest*—In most states the legal rate of interest has been established by statute; the rates varying considerably. In some states five percent is the legal rate; in others, six; in still others seven and eight. Where no specific amount is stated in the note, or the note simply states "With Interest," it is the presumption that the note carries the legal rate of the state where the note is made payable. It is usual, however, to designate the rate of interest, but in so doing care must be taken so that the rate shall not exceed the limit prescribed by statute in that state. For instance, in Arkansas the legal rate is six percent and the limit by law ten percent, and there is a penalty for usury, (which means more than the prescribed

limit) of forfeiture of the entire interest. In Michigan the legal rate is five percent and the limit is seven percent with a penalty of all the interest for usury. In some states the excess is simply forfeited. In Oregon the entire principal and interest is forfeited to the school fund.

*Agreement to pay attorney's fee in case of default*—This can be enforced in some states; in others, not, with various contingencies affecting the note. In Minnesota such an agreement can not be enforced, but it voids the negotiability of the note; in Maine it can be enforced, but does not void the negotiability of the note; in Maryland it can both be enforced and does not void the negotiability of the note.

These exactions are, however, purely statutory, and are subject to the particular state laws in which the notes are made, or made payable.

*Maker's and Endorser's waiver of presentation, etc.*—The provision in a note that

"The makers and endorsers thereof each hereby waive presentation for payment, notice of non-payment and notice of protest on this note"

adds materialy to the facility of handling the note. It absolves the payee from the usual formalities of presentation, protest, etc.; also greatly expedites the matter of suit in case payment is not made at maturity.

*Guarantee of Note*—It is usual to have notes endorsed; a good form being:

"For value received I hereby (or we hereby jointly and severally) guarantee payment at maturity of the within note."

*Guarantee of contract*—It is also quite common in contracts of sale to have the payments on the part of the vendee guaranteed by others not parties to the contract; sometimes on the contract itself; at other times by independent documents. If on the contract, the following clause is suggested:

"For value received I hereby (or, we, jointly and severally hereby) guarantee payment on the part of John Doe of the sums of money contracted to be paid by him in the within contract, and at the times and in the matter therein mentioned. This guarantee contemplates and covers any and all modifications which may be made in said contract by the parties thereto."

If the guarantee be an independent instrument, the following may be used:

"PITTSBURGH, PA., Jan. 1st, 1907.

"For a valuable consideration, the receipt whereof is hereby acknowledged, I, John Brown, (or, we hereby, jointly and severally,) hereby guarantee payment by the purchaser of the amount specified in a certain contract between Jonas White & Company and Thomas Black, dated December 27th, 1906, all covering the furnishing of certain apparatus to the value of fifty thousand dollars ($50,000.00) in accordance with the terms and conditions recited therein.

"This guarantee contemplates and covers any modification which may hereafter be made in said contract by the parties thereto."

*Application of payments*—The question as to the application of part payments made by a debtor who owes several amounts to the same creditor is often raised, and three rules of application have been established by the courts:

1st—The debtor has the first right to say to which debt the payment shall be applied, and any creditor accepting the payment made, qualified as to its application, is bound to apply it as directed.

2nd—If payment is made without any directions expressed or implied, the creditor has the right to apply it to any debt due him from the debtor, but it must be a just debt and not disputed.

3rd—When neither party has elected on any specific application, the payment is presumed to apply to the oldest debt.

# STORAGE BATTERIES (Cont.)

V. KARAPETOFF

Assistant Professor of Experimental Engineering, Cornell University

## OPERATION AND CONTROL OF STORAGE BATTERIES

11. *Selection of the System of Control*—Storage batteries are usually connected in parallel with generators, as shown in Fig. 2. Auxiliary apparatus necessary for the operation of batteries comprises:

(a) Switches, circuit-breakers, measuring instruments, etc.

(b) Means for charging the battery, and for regulating its current and voltage on charge and discharge.

The apparatus (a) is similar to that used with direct-current generators; the devices (b) are peculiar to storage batteries.

Various methods are used for charging and controlling the out-

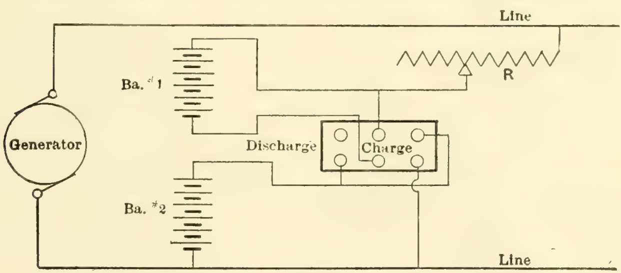


FIG. 8—CHARGING TWO HALVES OF A STORAGE BATTERY IN PARALLEL

put of batteries; the determining factors in the selection of a system of control being,—

(a) The purpose of the battery.

(b) Its size.

(c) Permissible limits of current and voltage fluctuations.

(d) The cost of the system.

(e) Whether hand or automatic control is desired.

The most important systems of control in practical use are described in the following paragraphs, beginning with the simplest system and including the most perfect automatic equipment.

12. *Charging Two Halves of the Battery in Parallel*—The simplest method for charging and regulating storage batteries is shown in Fig. 8. The battery is divided into two halves which are

connected in series for discharging and in parallel for charging. This is done in order to secure a sufficient voltage for charging, without affecting the line voltage maintained by the generator. An example will make this clearer. Consider a battery intended for an ordinary 110 volt lighting circuit. The voltage of each cell at the end of discharge is about 1.8 volt; therefore the number of cells required is $110 \div 1.8 = 62$. But the voltage necessary with this number of cells at the end of a charge is $= 2.6 \times 62 = 161$ volts, which is far above the line voltage. With the battery divided into two halves in parallel only 80.5 volts are required for charge; the excess voltage of the line is taken up by the rheostat $R$. Battery output on discharge is also regulated by this rheostat. This method though very simple is seldom used, except in small installations, where the loss of power in the rheostat is not objectionable.

A more economical method is to divide the battery into three equal parts; let them be denoted by $A$, $B$ and $C$. The parts $A$ and $B$ are first charged in series for one-half of the time necessary for full charge; then $B$ and $C$ are charged in series for one-half of the time, and finally $C$ and $A$ for one-half of the time. Less energy is wasted in the resistances with this arrangement, although it takes longer to charge the battery. The voltage at the end of the charge is $2/3 \times 161 = 107$ volts.

Other combinations are also possible, for instance, $A$ and $B$ may be connected in parallel with each other and in series with $C$. The set is charged at the full rate until $C$ is completely charged. Then $C$ is disconnected, $A$ and $B$ are connected in series, and the charge is completed.

13. *Experiment B—Charging Batteries in Sections*—Wire up the two halves of a battery as in Fig. 8 and make connections to a suitable generator. Provide a load in the form of adjustable resistances, and operate the installation under the following conditions:—

(a) The battery and the generator supplying power to the line.

(b) The battery being charged, the generator at the same time supplying power to the line.

(c) The battery alone supplying power, the generator being shut down.

(d) The generator working alone, the battery being disconnected for inspection and repairs.

For each of these conditions select a few characteristic loads (light load, medium load, full load and overload) and take all the

necessary ammeter and voltmeter readings, so as to have a complete record of the electrical relations in the circuit, with special reference to the performance of the battery. Observe voltage and current fluctuations when the load is varied first gradually and then suddenly. Devise a convenient arrangement of switches for charging the battery in three parts, as explained in § 12. Connect the battery accordingly and observe the process of charging.

14. *End-Cell Switches*—In many small installations there is no demand for current during the day. In such cases the battery connections shown in Fig. 9 are used. The battery is charged during the day, when the main switch $S$ is open, the voltage on the generator being raised to the required 161 volts for charging the battery. During discharge the battery voltage and output are regu-

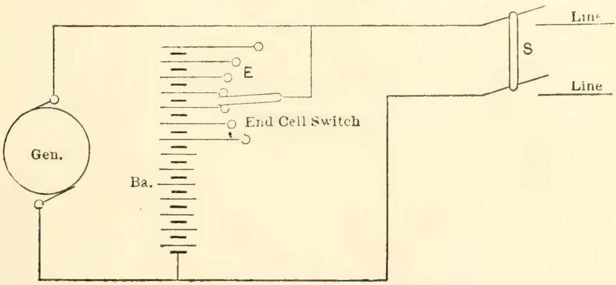


FIG. 9—USE OF A SINGLE END-CELL SWITCH
Line switch $S$ opened when the battery is being charged.

lated by the so-called *end-cell switch E*, by means of which more cells may be connected into the circuit in proportion as the voltage of each cell drops during the discharge.

End-cell switches are sometimes used in installations where charging is done by means of special machines which are called "boosters". Storage batteries in stations and sub-stations of the Edison illuminating companies in large cities are regulated by end-cell switches and charged by boosters. Large end-cell switches are sometimes operated by electric motors, which may be started or stopped either by the switchboard attendant, or automatically by a contact voltmeter.

The contact on the arm of an end-cell switch must be wide enough so that the battery circuit would not be opened while the arm is moved from one segment of the switch to the next. On the

other hand, when the arm bridges two adjacent segments, the cell connected to these two segments is short-circuited, which is not permissible. Therefore the arm contact is made in two parts with a *protective* resistance between them, this resistance limiting the current in the short-circuited cell during the instant when the arm is moved from one contact to the next.

In some cases it is not practicable to have the main switches opened while the generator voltage is raised for the charge; at the same time the size of the installation does not warrant the complication of a booster. Two end-cell switches are used in such cases, as shown in Fig. 10. By means of the end-cell switch $E_1$ the required voltage is maintained on the line, while the charge is regulated by the generator field rheostat and the end-cell switch $E_2$.

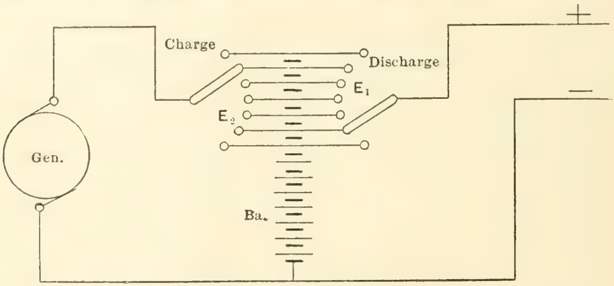


FIG. 10—BATTERY CONNECTIONS WITH A DOUBLE END-CELL SWITCH

The generator charges the battery at a high voltage and at the same time supplies the line at the normal voltage.

With this scheme, the end cells are carrying the sum of the charging current and the line current, and are therefore charged faster than the rest of the battery. Actual practice does not show, however, any disadvantage in such an arrangement, provided the charging is done during the hours of small demand. It will be easily seen that more contact points are necessary with a double end-cell switch than with a single end-cell switch.

Fig. 11 shows the complete diagram of connections for the arrangement according to Fig. 10. The switch $S_1$ controls the generator circuit, $S_2$—the battery circuit; $S$ is a double-throw switch which makes connections for charging or discharging. For charging the battery, $S$ is thrown to the right, and the switches $S_1$ and $S_2$ are closed. The charging current flows from the + terminal of

the generator through $S$ to the charging end-cell switch $E_2$; thence through the battery, ammeter $A_2$, overload circuit-breaker $CB_2$, underload circuit-breaker $CB_1$, and switch $S_2$ to the negative terminal of the generator. At the same time the line is supplied with current through the discharge end-cell switch $E_1$ and the ammeter $A_1$. The underload circuit-breaker is used in order to prevent the battery from sending current back into the generator. An underload circuit-breaker may be used only in battery installations in which the load is varying slowly, so that there are distinct periods of charge and discharge. In railway installations the load is rapidly fluctuating, and the battery current is reversed sometimes every few sec-

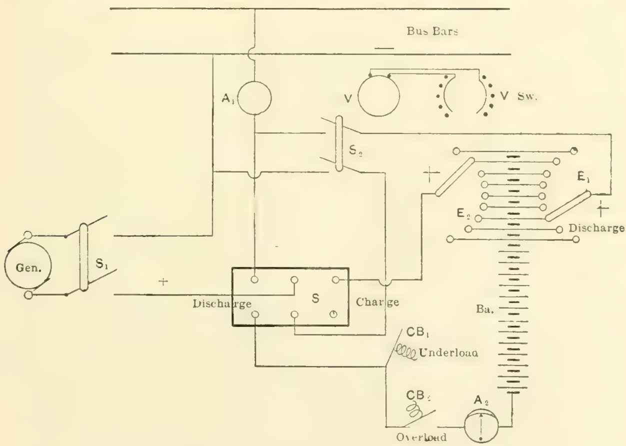


FIG. 11—THE SYSTEM ILLUSTRATED IN FIG. 10 SHOWN MORE IN DETAIL

onds. No underload circuit-breaker could be used under such conditions.

For discharging the battery into the line, in parallel with the generator, the switch $S$ is thrown to the left; this cuts the charging end-cell switch $E_2$ out of the circuit, while the underload circuit-breaker $CB_1$ is short-circuited by the lower blade of the switch $S$. The discharge is regulated by the end-cell switch $E_1$ and the field rheostat of the generator.

If it is desired to shut down the generator, the switch $S_1$ is opened, and the battery continues to supply current alone. This is usually the case late at night and early in the morning, when the

demand for current is quite small. If the switch $S_2$ is opened instead of $S_1$, the battery is disconnected from the line, while the generator continues to supply the power. $V$ is a voltmeter which by means of the voltmeter switch *V Sw.* can be connected so as to show at will,—generator voltage, battery voltage, or line voltage. In addition, a portable 3-volt instrument is always used in storage-battery plants for measuring the voltage of each individual cell.

15. *Experiment C—End-Cell Switch Control of Storage Batteries*—The connections with a single end-cell switch are shown in Fig. 9; those with a double end-cell switch in Fig. 10, or more in detail in Fig. 11. Try both systems in actual operation under the conditions specified in the Experiment B.

Report actual diagrams of connections and numerical results of the test. State voltage fluctuations with sudden variations of the load, and give the relative fluctuations of the current in the generator and in the battery. Figure out the number of points necessary on the single end-cell switch and on the double end-cell switch.

*(To be continued.)*

# TESTS AND OPERATING RESULTS ON THE 5 500 KW TURBO-GENERATOR OF THE INTERBOROUGH RAPID TRANSIT COMPANY

IN the tables and diagram given herewith there will be found the results of tests made on the 5 500 kw turbo-generator at the power house of the Interborough Rapid Transit Company. The economy test gives the first authentic information regarding the results obtainable with this very interesting installation. The tests are especially valuable, as they were conducted under the direct

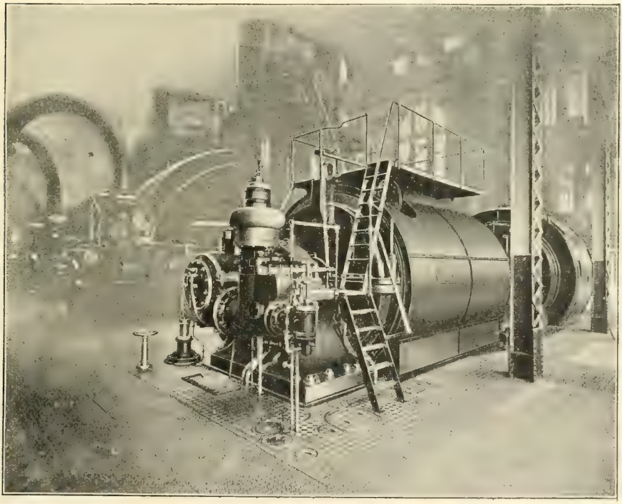

FIG. I—5 500 KW TURBO-GENERATOR SET AT INTERBOROUGH RAPID TRANSIT COMPANY'S POWER HOUSE

supervision of Mr. H. G. Stott, of the Interborough Company, who possesses unusual perception in analyzing power station economies. It is, therefore, safe to assume that these tests are authoritative in every sense.

This station presents a good opportunity to obtain reliable information regarding the relative merits of the reciprocating and tur-

bine type of prime movers as the turbo-generator runs in parallel with eight 5 000 kw Corliss units, a governor of special design being employed to give a proportionate distribution of load. The illustration in Fig. 1 gives a good idea of the relative sizes of the two types of machines.

The detailed operating record was prepared by Mr. Lawrence, chief engineer of the Interborough Company, and shows that this installation has been carrying a continuous overload for a great part of the time during the last year.

### TURBO-GENERATOR TESTS

Purpose—The two most important relations to be determined were :—

First—The variation of steam consumption with load (constant thrust-bearing settings).

Second—The variation of water rate with vacuum (constant load 5 000 kw).

Methods of Testing—Before commencing the tests, preliminary trials were invariably made to test apparatus and connections. Final trials were governed as to length, by condition of station load and water rate as determined by hourly averages, no test being considered acceptable unless the last consideration was observed to be correct within a reasonable degree. Readings were taken simultaneously at fifteen-minute intervals, signal therefor being by whistle. An hourly log was kept to determine fluctuations in water rate ; final results in all cases, however, were determined from averages without regarding hourly results.

*Metering*—The load on the turbo-generator was measured electrically by means of four balanced three-phase indicating wattmeters of the induction type connected to current and potential transformers located at the terminals of the generator. A current transformer was placed in series with each of the three armature conductors and two potential transformers were connected across phases one-two and two-three respectively.

*Calibration of Apparatus*—Previous to use in connection with the tests the apparatus, such as thermometers, gauges, meters and scales, was calibrated and placed in accurate adjustment.

*Water Consumption*—Total water measurements were made of the condensed exhaust after discharge from the vacuum pumps. The flow of water was continuous, but diverted at convenient intervals from one to the other of two pairs of weighing tanks mount-

ed on two twenty-ton scales. Water rate indications were based upon indicated switch-board load, no allowance being made for electrical loss.

The results of the tests as given in Table I and represented by the curves in Fig. 2 show extremely consistent results. Owing to the large over-load margin of this machine, the water rate continues to decrease for some time after full-load is reached and the total increase in economy from one-half load to fifty percent overload is about seventeen percent. At fifty percent overload the water rate is about 17 pounds per kw-hr., which corresponds to

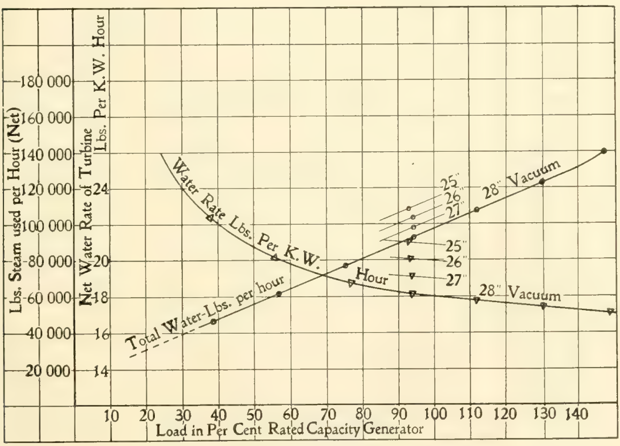


FIG. 2—CURVES SHOWING RESULTS OF TESTS

11.75 pounds per brake hp-hr. At full-load the water rate is 17.9 pounds per kw-hr. or 12.4 pounds per brake hp-hr.

*Vacuum*—The effect of a vacuum is very clearly shown by the tests. Between 26 inches and 28 inches vacuum (referred to 30 inches, barometer) the rate of change per inch of vacuum is five percent of the average corresponding water rate. With lower vacuum the percentage changes to about 3.5 percent per inch of vacuum.

*Percent of Moisture*—These tests were conducted with saturated steam containing as high as 2.5 percent moisture. Had superheated steam been used it is probable that the full-load steam consumption would have been approximately 11 pounds per brake hp-hr. with 100 degrees superheat.

TABLE I—RESULTS OF TESTS ON 5 500 KW TURBO-GENERATOR.

| | Nominal Load—Kilowatts | | | | | | | Nominal Vacuum—Inches | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 000 | 3 000 | 4 000 | 5 000 | 6 000 | 7 000 | 8 000 | 25″ | 26″ | 27″ | 28″ |
| Number of tests.................... | 11 | 10 | 6 | 9 | 8 | 13 | 20 | 17 | 16 | 15 | 9 |
| Duration (hours)................. | 4 | 6 | 6 | 6 | 6 | 3 | 3 | 4 | 4 | 5 | 6 |
| Throttle pressure* (lbs. gauge) | 152.9 | 152.8 | 152.5 | 152.5 | 149.9 | 149.7 | 151.6 | 149. | 150.7 | 152.2 | 152.5 |
| Quality steam (percent dry)... | 97.16 | 97.87 | 47.80 | 97.86 | 97.46 | 97.02 | 97.15 | 97.45 | 97.58 | 97.62 | 97.86 |
| Vacuum (in. Hg.) ................ | 28.09 | 28.09 | 28.04 | 27.98 | 28.01 | 28.02 | 27.73 | 24.97 | 26.20 | 27.25 | 27.98 |
| Barometer (in. Hg.) ............. | 29.66 | 29.50 | 30.13 | 29.94 | 30.35 | 30.35 | 29.97 | 29.80 | 30.00 | 30.25 | 29.94 |
| Corrected vacuum (in. Hg.) ... | 28.40 | 28.55 | 27.94 | 28.02 | 27.69 | 27.70 | 27.78 | 25.13 | 26.20 | 27.04 | 28.03 |
| Load switchboard† (kw)........ | 2 060 | 3 106 | 4 068 | 5 175 | 6 125 | 7 134.5 | 8 174 | 5 122 | 5 174 | 5 142 | 5 175 |
| Wet steam per hour (lbs.)...... | 47 573 | 63 624 | 78 468 | 96 149 | 111 382 | 127 082 | 144 210 | 110 330 | 106 155 | 100 267 | 96 149 |
| Dry steam per hour (lbs.)...... | 46 222 | 62 269 | 76 742 | 94 091 | 108 553 | 123 295 | 140 100 | 107 517 | 103 586 | 97 881 | 94 091 |
| Dry steam per kw-hour (lbs.).. | 22.44 | 20.05 | 18.87 | 18.18 | 17.70 | 17.27 | 17.14 | 20.99 | 20.02 | 19.04 | 18.18 |
| Percent rated load............ | 37.5 | 56.5 | 74.0 | 94.0 | 111.5 | 130.0 | 148.6 | 93.2 | 94.0 | 93.6 | 94.0 |

*To nearest one-tenth lb. †To nearest kw.

OPERATING RECORD

The detailed operating record in Table II summarizes the results of the year's operation, showing the running time, idle periods, power generated and average load for each month and the ratio in percent of this load to full-load.

*Duration of Runs*—During ten different periods the turbine ran continuously for from seven to nine days under full load. During five periods of ten days or over the machine carried an average load of 107 percent rating. The longest run without stops was sixteen days at full-load. Between September 19 and October 19 inclusive, the turbine made but three stops totaling twenty hours, fourteen to clean the generator and condensers and the remaining six idle.

*Summary*—The summary shows that during 65 percent of the time the turbine was in operation and carried an average load two

TABLE II—SUMMARY OF YEAR'S OPERATION, 1906.

| Date | Time run— Hours | Time run— Minutes | Percent Elapsed Time | Kw-Hours Generated | Average Load Kw-Hours | Percent Rating |
|---|---|---|---|---|---|---|
| January | 239 | 37 | 32.2 | 1 148 900 | 4 795 | 87.2 |
| February | 221 | 47 | 32.8 | 1 129 250 | 5 091 | 91.2 |
| March | 288 | 58 | 38.8 | 1 494 950 | 5 173 | 91.5 |
| April | 222 | 03 | 30.8 | 1 274 200 | 5 738 | 104.2 |
| May | 599 | 12 | 80.4 | 3 424 550 | 5 715 | 104.0 |
| June | 631 | 32 | 88.2 | 3 454 350 | 5 470 | 99.5 |
| July | 704 | 15 | 94.7 | 3 576 700 | 5 079 | 92.3 |
| August | 478 | 17 | 64.2 | 2 598 100 | 5 432 | 98.8 |
| September | 617 | 20 | 85.7 | 3 463 900 | 5 611 | 102.0 |
| October | 490 | 50 | 66.0 | 2 966 550 | 6 044 | 109.8 |
| November | 551 | 30 | 76.8 | 3 332 375 | 6 044 | 109.8 |
| December | 675 | 05 | 90.8 | 4 190 425 | 6 207 | 112.7 |
| Total | 5 720 | 26 | ........ | 32 054 250 | ........ | ........ |
| Average | ........ | ........ | 65.3 | ........ | 5 603 | 101.8 |

percent above rating, while during the month of December it averaged thirteen percent above rating. The total output for the year was 32 054 250 kw-hr. For five different periods of ten days under continuous load, the turbine averaged 140 422 kw-hr. per day.

Comparing this with the economy of a large Corliss engine with an assumed mechanical efficiency of 91 percent, the engine would have to show an equivalent water rate of close to ten pounds per i.h.p. per hour to equal the performance of this turbine.

# EXPERIENCE ON THE ROAD

## DRYING INSULATION WITH ELECTRIC CURRENT

H. W. TURNER
Consulting Engineer, London, England

DURING a recent visit to Italy the writer had some experience in overcoming insulation difficulties on some 20 000 volt air-cooled transformer coils by new and novel methods which have since been adopted as regular shop practice. As the factories at Milan are supplied with electric power transmitted from a distance, steam for heating the drying ovens is not available; and, as coal is very high priced, coke is employed for this purpose, with the result that the temperatures of the ovens fluctuate with the firing to a very wide extent.

Insulation troubles, due to insufficient baking and hardening of the insulation varnishes, were overcome by adding ventilating fans to supply fresh air for oxidizing and hardening the varnish. The oven temperature was raised and kept more uniform by the aid of automatic temperature recorders and the varnishes were thinned to a better working density.

As the writer wished to get practical results without remaining at the works the seven or eight weeks ordinarily consumed in turning out these transformers, he devised the new method described below.

A motor-generator set was installed in the winding department from which direct current was supplied to the transformer coils which were being insulated. The coils had already been given a first dipping and been oven dried over night so that the insulation and varnish next to the copper was perfectly dry and hard. The coils were connected six in series and sufficient current passed through them to keep the temperature, as registered by thermometers placed on the coils, between 80 and 90 degrees C. Bias-cut treated linen tapes were used instead of cotton tapes and insulating varnish was applied immediately after each layer of tape. Two men put on the tape and applied the varnish consecutively to each of the coils. As soon as the last coil of the series had been taped and varnished the first one was dry enough for the next layer of tape and varnish. In this way several layers of tape could be applied in a day, so that instead of eight weeks, less than one week was required for this work. In addition there was another great

advantage as the finished coils were at least twelve millimeters thinner than by the old method, thus allowing more air ventilating space between the coils when installed.

Obviously drying from the inside is better than drying from the outside, for with the latter method, the films of varnish seal up and retain the moisture and air before the inner layers of insulation are safely dry. The saving in time, labor and material by the use of this method have been such that two of the four drying ovens at this works have been permanently shut down and the space filled by a second motor-generator set.

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## NOTES ON TESTING

V. W. SHEAR

IT may be of some value to inexperienced men, who expect to become engaged in the testing of large electrical apparatus, to review briefly a few practical points which enter into the routine of this work and go far to make it rapid, accurate and successful.

Assuming that one has just arrived upon the testing floor and sees around him a great complication of machines, switchboards, cables and men, the great question in his mind is, why each one is doing a certain thing and how will *he* do it? He is told to do some very simple thing, such as take speed (so simple that many never learn to do it accurately) or hold the voltage steady by means of a rheostat. He gets a chance to look around him and to answer a few of the why's and how's. Very soon he must make connections more or less complicated and read meters. Using all judgment with regard to troubling busy men, the questioner will be wise to lose no time in tracing out exactly the circuits that are being connected up and learning what results are expected from that particular way of doing it. He is sure to need that knowledge in a short time.

There is no aid to intelligent work like making diagrams of all circuits on switchboards, tables, relays, etc., which are not in plain sight. They need be only rough sketches that can be carried around ready for instant reference. One is then sure of the connections which he is making. His previous training and experience must tell him whether or not they are the correct connections. It is often of great advantage to have sketches of the circuits on which one

may work later. This knowledge will be found valuable in making the work easier and better, in giving evidence of foresight and in increasing one's efficiency. Accuracy is much easier when made a habit from the start and consistently followed out. The writer found it very helpful to sum up each day his errors large and small. Few days were spent free from criticism, but the results of this self examination was better work.

A good tester never anticipates results. It is his chief temptation, however. The most staid old apparatus will occasionally give most unlooked for results. Such results must not, through laziness or fear of criticism, be corrected to look like usual results; the cause should be investigated. Judgment should also be exercised regarding the precision required in commercial testing. Meters should not be read to four figures when two figures are sufficiently accurate and more rapid.

The beginner expects ideal conditions. He finds them quite otherwise. Certain apparatus is out of repair; the voltage from the power-house is not always steady; lights do not always burn; someone else always has the meters, rheostats and cables that are needed; therefore the whole place is wrong and ill-managed, and valuable time is therefore spent in grumbling. Are you sure that if burdened with the responsibility of accomplishing a vast amount of work, accurately, rapidly and withal economically the department would be in better shape under your management?

Many men fail to do their best work because of an almost utter lack of any feeling of responsibility. A man never knows when the foreman is asking the man in charge of a squad how that man is getting along. Aside from the general advisability of always doing one's best, it is not safe to do otherwise, if desiring promotion.

There is no work calling for such a mingling of caution and firmness as the testing of large machines. Caution is required when deciding just what to do; but above all things do not allow caution to stand in the way of throwing each switch as though you meant something by it, nor keep you continually hesitating. There is no safeguard against burns and accidents like eternal vigilance and constant carefulness, combined with a positive way of carrying out your decisions. These qualities will afford the surest means of acquiring a well-ground self-confidence as well as the confidence of your superiors and associates.

# THE ELECTRIC JOURNAL

VOL. IV. AUGUST, 1907 NO. 8.


**Power-Factor Correction**

Mr. Nesbit's article on "Synchronous Motors for Improving Power-Factor" in this issue of the JOURNAL calls attention to an important element in power-station operation. The question of low power-factor in its relation to the limitation of the capacity of electrical apparatus and to the relative capacity of engines and generators, is one that has been neglected in the design of too many power stations. The result of this neglect is evident in the unbalanced capacity of engines and electrical equipment which make useless a certain part of the station equipment, in poor voltage regulation and in some cases in the inability to maintain normal voltage even at the generator.

There can be no general solution of the problem introduced by low power-factor, the proper procedure in any given case depending on a large number of conditions. Mr. Nesbit has indicated the two possible remedies, viz.: Increasing the capacity of the generators and other electrical apparatus to provide for the increased current caused by low power-factor, or installing synchronous motors to raise the power-factor. In the second remedy the synchronous motors may be loaded mechanically or may be operated without load solely for their corrective effect.

Whatever the remedy adopted, the first consideration should be given to simplicity and reliability in operation. As pointed out by Mr. Nesbit, power-factor correction by synchronous motors is obtained most economically when a mechanical load is available for the motor. It is not justifiable, however, to obtain this economy at the expense of good operating conditions. Synchronous motors should not be installed where such motors are not adapted to the mechanical load available or where they will not receive intelligent care. It should be remembered that the power-factor regulation secured by the use of synchronous motors is not automatic but depends on the adjustment of the field current. By improper adjustment, through lack of attention or lack of knowledge on the part of the operator, a synchronous motor may lower the power-factor to a greater extent than would an induction motor installed in the same place.

There are only a few cases in which the installation of synchronous motors, running light in order to improve the power-factor, will work out economically as compared with the increase in generator capacity necessary to obtain the same result. Synchronous motors used in this way simply act as generators to supply magnetizing current to the system, and hence the problem is one of the relative cost of one large generator and of one large generator and a smaller generator. Usually one generator can be installed for less money than two smaller ones. If, however, the main generators are of low speed on account of their prime mover, two smaller generators will probably cost less on account of the high speed at which synchronous condensers may be operated. Another factor that may be favorable to the installation of the synchronous motor, running light, will be the relative cost of generators and of the transformers and feeders. Since the synchronous condenser when installed at the end of a line reduces the required capacity of all of the electrical equipment, if the transformers and feeders represent a large investment compared with the generator, the saving in the former may easily be sufficient to pay for a synchronous condenser.

F. D. Newbury

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**Power Station Data**

The data compiled by Mr. H. G. Stott, superintendent of motive power of the Interborough Rapid Transit Company of New York, giving the principal dimensions of the power houses and sub-stations operated by that Company, and published in this issue of the Journal, gives information on what are probably the two largest steam-driven systems in the world.

The service required of these stations is most exacting, and the great success which has attended their operation since they were put into commission speaks most emphatically of the high quality of the engineering skill which was employed in their design and inception, the thoroughness of the workmanship on both the machinery and buildings, and the efficiency of the operating organization.

While these power stations mark the highest development of the upright steam-driven type, it is also very probable that they are the last stations containing units of this type and magnitude which will be built. The great success which has attended the operation of turbo-generators, both from the standpoint of efficiency and economy of operation, will, in all probability, insure the adoption of that type of prime mover for all large installations of the future where steam is used.

W. K. Dunlap

**Standardization Rules—A. I. E. E.**

In the early part of 1898 there was a topical discussion at a meeting of the American Institute of Electrical Engineers on the standardizing of electric apparatus. The desirability of standardization was generally admitted and the scope, policy and methods of procedure were discussed. As the result a committee was appointed, which reported the following year. This report was revised in 1902. A further revision proposed by the standardization committee has just been approved by the board of directors and issued. It is interesting to note that Messrs. Crocker, Kennelly, Mailloux, Steinmetz and Scott, who have been among the active workers of the committee which has just reported, took part in the preliminary discussion nine years ago.

Under the broad term "standardization" might be included a vast number of items, ranging from absolute electrical units to shaft diameters of motors. The rules as formulated, however, have as their principal aim the embodiment in useful form of that which is generally recognized as good practice. As the criterion is good practice rather than absolute or theoretical standards, it follows that the rules must be modified and added to as the art advances.

Much of the material might properly be termed "useful information", as it has little to do either with formal standardization or with specific rules. In fact, the title, "Standardization Rules", is quite open to criticism, as there is comparatively little that can properly be termed "standardization" in its narrower sense, and there is a great deal which certainly cannot properly be termed "rules". The committee has evidently disregarded both the limitations which the title would impose and those which a rigorous logical classification would give and has aimed to present that which will be useful to electrical engineers.

The present revision has consisted in a careful examination of former statements, the elimination of paragraphs which refer to matters of obsolete interest, the addition of new material, and a radical reclassification and rearrangement. At almost every point the committee has encountered the questions of scope and policy. Many of the present paragraphs might easily be elaborated into dissertations covering many pages of exposition and explanation. In general, the purpose has been to give correct general guidance, setting forth the underlying principles and the conditions which must be met, without entering into restrictive methods as to details. It is obviously impossible to make a single statement which will cover the wide variety of conditions which is liable to occur in practice, hence the term "ur

less otherwise specified" is frequently inserted, indicating that the rules apply to general or average conditions and that no arbitrary limits are intended to be placed upon the exercise of intelligent judgment in dealing with exceptional cases or new conditions.

In a number of instances particular subjects have been considered by sub-committees, which have called in experts. One committee of this kind took up the subject of railway motors. Several lengthy meetings were held, at which a dozen or more designing and consulting and operating railway engineers were present. The desire was to secure a simple, concrete statement for expressing the rating of the motor which could be used for the designation of given motors, for the comparison of the relative outputs of different motors and for the selection of a motor for a given service. Different definitions and methods of rating were proposed, each of which met with criticism. As the outcome, it was recognized that it was impossible to state in simple terms the characteristics of a motor which would give sufficient information as to its performance under the various conditions which occur in service and that the choice of a railway motor is usually not a simple matter, such as the selection of a motor for ordinary constant-speed work, and that the specific conditions of service as well as the performance of the motor under these conditions must be taken into account. Consequently, instead of a definition there resulted a dissertation in which the general problem and the methods to be followed in the selection of a motor are set forth.

Another sub-committee had under consideration the standardization and testing of lightning arresters. It was found, however, that the subject was not sufficiently definite and crystallized to be properly presented in the Standardization Rules at the present time. It was considered desirable, however, that the matter should be taken under general consideration by electrical engineers. At the request of the committee papers were prepared and presented on this subject at the Niagara Falls convention.

Probably the members of the committee realize more fully than others the incompleteness and inadequacy of the present report when compared with an ideal standard. It has been presented, however, with the belief that it will be useful in its present form and that additions and modifications will be made in future revisions.

CHAS. F. SCOTT

# SYNCHRONOUS MOTORS FOR IMPROVING POWER-FACTOR

WILLIAM NESBIT

THE use of synchronous motors for introducing leading currents into circuits of low-power-factor for the purpose of improving the power-factor is now being given more attention than formerly. This may be due to the fact that in the past the average electrician in charge of induction motor-driven plants did not as fully understand the subject of low power-factor, its many evils and their remedies, as he does to-day.

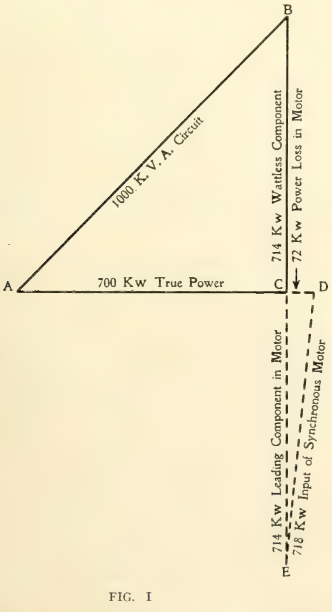



FIG. I

It is the intention to consider in this article the most efficient point to which the power-factor should be raised, the advantage in making the synchronous motors give out mechanical power (in addition to improving the power-factor) and to point out the advantage derived by installing a synchronous motor in a specific case.

The power-factor of induction motor-driven plants usually varies between 55 and 85 percent. A power-factor of 55 percent is unusual and would indicate that some of the motors were under-loaded. Such a condition would, of course, be improved by replacing such motors with motors of smaller capacity. The power-factor of alternating-current arc lamps is approximately 70 percent, that of induction motors in capacities between one and 100 hp is for full-load 80 to 90 percent and for half-load 60 to

80 percent. Many plants are to-day operating at a combined power-factor of 70 percent.

As an illustration the effect of a synchronous motor on a circuit delivering 1 000 k.v.a. at 70 percent power-factor (700 kw true energy) will be considered. The 1 000 k.v.a. will be considered the full-load k.v.a. rating of the steam driven direct-connected generators and it will be assumed that there is a demand for more power to the extent of 200 or 300 hp. This may be obtained either by raising the power-factor of the present generator load, or by installing a new generator and engine. If the generators in this plant were rated at 100 percent power-factor as was often the case in the past and is to a surprising extent to-day, then the plant is very badly out of balance for 70 percent power-factor operation. In this case the engines, boilers, piping, wiring and in fact all the equipment with the exception of the generators, have sufficient capacity to drive the generators at 100 percent power-factor rating (1 000 kw true energy). On account of the generators being rated at 1 000 kw, 100 percent power-factor, they can deliver only 700 kw true power at 70 percent power-factor. Therefore the available capacity of this plant has been reduced from 1 000 to 700 kw or 30 percent, on account of generators being installed having a 100 percent power-factor rating in place of a 70 percent power-factor rating. If it was not the intention to install any synchronous motors in this plant but simply allow the power-factor to take care of itself, then larger generators should have been installed on these engines or smaller engines on the present generators. If generators having a combined rating of 1 430 k.v.a in place of 1 000 k.v.a rating had been installed then this plant would deliver 1 000 kw true power (1 430 k.v.a. at 70 percent power-factor). Later the result of installing a synchronous motor in this plant will be considered.

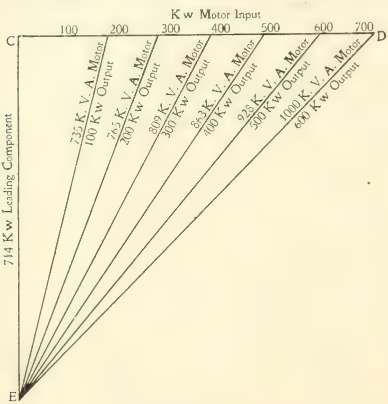


FIG. 2

POWER-FACTOR RAISED TO UNITY

Fig. 1 shows graphically the conditions existing in this plant. Here *AB* represents the 1 000 k.v.a. load, *AC* the true power (700 kw) and *BC* the wattless component (714 kw). The angle *BAC* is the angle of lag, *AC* representing the direction of voltage and *AB* the direction of the current. Since there is $\sqrt{1\,000^2 - 700^2} = 714$ kw wattless component in the circuit lagging 90 degrees behind the voltage, in order to raise the power-factor to 100 percent it would be necessary to introduce the same amount of leading wattless power into the same circuit. This is shown in Fig. 1 by the line *CE*, 180 degrees from *BC*. Assuming the true watt loss in the motor as approximately ten percent of its full-load rating and drawing the line loss *CD* (72 kw in phase with the true power of the circuit), the the synchronous motor triangle *CED* is formed, in which *ED* (718 k.v.a.) is the input of the synchronous motor, *EC* (714 kw) its leading wattless component and *CD* (72 kw) its true power component. A synchronous motor therefore having a capacity of 718 k.v.a. floating on this circuit without doing any mechanical work would raise the power-factor of this circuit to unity and reduce the load on this plant from 1 000 k.v.a. to 772 kw (700+72) or a reduction of 228 kw. This gain in capacity has been obtained at the expense of the first cost of this 718 k.v.a. synchronous motor and the cost of furnishing the power lost in the motor.

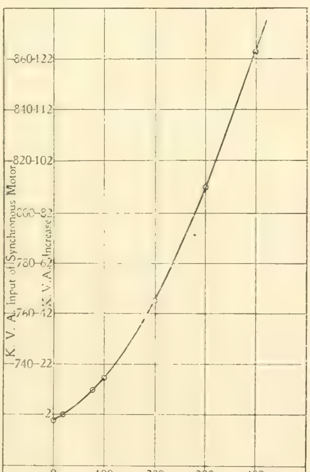



FIG. 3

From the above it will be seen that, in case the synchronous motor is not made to give out any mechanical power, the capacity of the synchronous motor for obtaining unity power-factor is quite large compared with the gain in plant capacity. In this case a 718

k.v.a. synchronous motor reduces the generator load only 228 k.v.a.

Fig. 2 shows graphically the conditions when the synchronous motor in addition to raising the power-factor to unity is made to furnish varying amounts of mechanical power. Here *EC* (714 kw) represents the lagging component in the circuit and the leading component in the synchronous motor. *CD* represents the true kw input of the synchronous motors. The six diagonal lines represent the capacity required for the motor that will, in addition to raising the power-factor to unity, deliver 100, 200, 300, 400, 500 and 600 kw respectively in the form of mechanical power. At the points where the diagonal lines intersect the line *CD*, the input of the synchronous motor may be read off (assuming ten percent loss in the motor). Thus a 1 000 k.v.a. motor will deliver 600 kw mechanical power with an input of 600+100 or 700 kw.

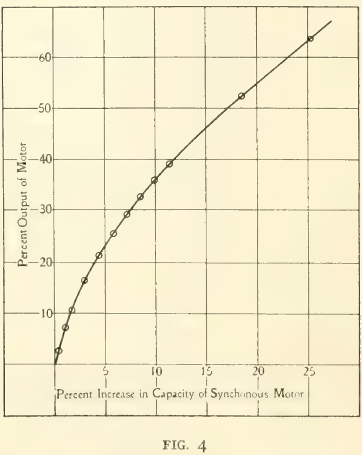



FIG. 4

The large returns in the form of mechanical power delivered by the synchronous motor for slight increases in capacity is shown in the form of a curve in Fig. 3. By consulting this curve it may be seen that by increasing the capacity of this synchronous motor from 718 to 720 k.v.a. or by two k.v.a. it will deliver 21 kw mechanical power in addition to raising the power-factor of the circuit to unity By increasing its capacity to 830 k.v.a. or by 12 k.v.a. it will deliver 79 kw mechanical power. By increasing its capacity to 1 000 k.v.a. it will deliver 600 kw mechanical power.

Looking at it another way two k.v.a. increase in capacity of synchronous motor gives a return in the form of mechanical power of 1 050 percent, 12 k.v.a. increase gives 658 percent, and 282 k.v.a. increase gives 212 percent. The percent (based on the rating of the 718 k.v.a. motor) available in mechanical power corresponding

to various percent increases in the capacity of the motor is shown in the form of a curve in Fig. 4. Thus five percent increase in capacity of the synchronous motor enables it to deliver 23.5 percent of its 718 k.v.a. rating in the form of mechanical power; ten percent increase, 36 percent, and 25 percent increase, 63.5 percent.

The importance of making the synchronous motor give out mechanical power is therefore self-evident and the more mechanical power which can be utilized from it the less will be the amount chargeable to it for raising the power-factor.

### POWER-FACTOR RAISED TO LESS THAN UNITY

As it is seldom economical or necessary to raise the power-factor of a circuit to unity, the raising of the power-factor of this circuit to 90 percent in place of 100 percent will be considered. Fig. 5 shows graphically the new conditions, the motor in this case not delivering any mechanical power. Here,—

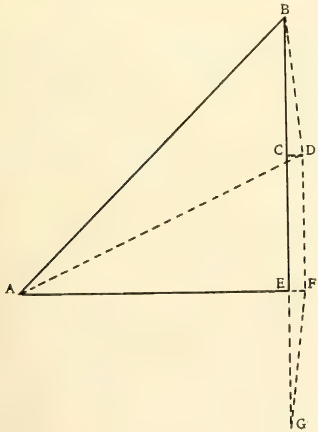


FIG. 5

$AB$=1 000 k.v.a. load at 70 percent power-factor

$AE$=700 kw power component.

$BE$=714 kw lagging wattless component

$CD=EF$=Power input of synchronous motor

$EG=BC$=Leading component of synchronous motor

$BD=FG$=Capacity of synchronous motor required

$AF$=True energy in circuit including motor input

$DF$=Lagging wattless component in circuit of 90 percent power-factor.

$AD$=k.v.a. load in circuit of 90 percent power-factor.

In order to determine the value of $FG$ it may be noted that:—

$AE=0.7\,AB$

$AF=0.9\,AD$ or $AD=\frac{AF}{0.9}$

$BE=0.714AB$

$CD = 0.1BC$ (assuming approximately ten percent motor loss)

Now, $AF = AE + CD$

$AD^2 = AF^2 + DF^2$ or $DF^2 = AD^2 - AF^2$

$BC = BE - DF$

$$BC = 0.714AB - \sqrt{AD^2 - AF^2} = 0.714AB - \sqrt{\frac{AF^2}{0.81} - AF^2} =$$

$$0.714AB - \frac{AF}{0.9}\sqrt{0.19} = 0.714AB - \frac{0.7AB + 0.1BC}{0.9}\sqrt{0.19}$$

$$= 0.714AB - 0.339AB - 0.0484BC$$

or, $1.0484BC = 0.375AB$

$BC = 358$ kw leading current in motor

$CD = 36$ kw input of motor

$FG = 360$ k.v.a. capacity of motor

The capacity of the synchronous motor required to raise the power-factor of a circuit to any value may be obtained by the above method, assigning the proper values to the various equations for the power-factor required and the power-factor of the circuit before the synchronous motor is added. The capacity of the motor required may be very closely approximated by laying it out graphically on a fairly large scale.

Below is given the capacity of motors required to raise the power-factor to various amounts:—

| Power-Factor Percent. | Synchronous Motor K. V. A. | GENERATOR Load K. V. A. | GENERATOR Increase in Capacity | Relative Gain K. V. A. |
|---|---|---|---|---|
| 75 | 107 | 935 | 65 | 0.61 |
| 80 | 177 | 897 | 103 | 0.58 |
| 85 | 264 | 855 | 145 | 0.55 |
| 90 | 360 | 818 | 182 | 0.51 |
| 95 | 470 | 787 | 213 | 0.45 |
| 100 | 718 | 771 | 229 | 0.32 |

In the above table the second column contains the k.v.a. capacity of the synchronous motor required to raise the power-factor of this circuit (including motor loss) to the values given in the first column. The third column gives the k.v.a. load with the motor in use. The fourth column gives the reduction in generator load. The last column gives the k.v.a. generator capacity gained per k.v.a. capacity of synchronous motor for the power-factors given.

Fig. 6 shows the above in the form of a curve. At 75 percent power-factor for each k.v.a. capacity in synchronous motor, 0.61 k.v.a. additional generator capacity and for 100 percent power-factor for each k.v.a. in capacity in synchronous motor, 0.32 k.v.a. additional capacity in generators is made available. In other words—the return in additional generator capacity is, at 75 percent power-factor, about double what it is at 100 percent power-factor. This would indicate that an increase of say five percent in the power-factor can be obtained more cheaply when the power-factor is low than when it is high and that it would probably not pay to attempt to increase the power-factor above about 95 percent.

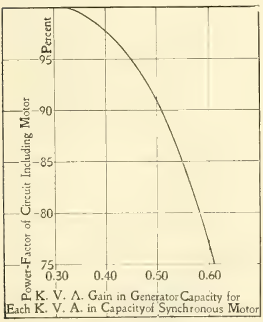



FIG. 6

ADVANTAGE OF A SYNCHRONOUS MOTOR IN A SPECIFIC CASE

Since it is desirable to make the synchronous motor do mechanical work in addition to improving the power-factor and since the greatest returns may be looked for when the power-factor is raised to a point in the neighborhood of 95 percent, a consideration will be given of the cost of installing a synchronous motor in the case which has been considered and the advantage derived. Assuming that the plant is delivering its normal capacity of 1 000 k.v.a. at 70 percent power-factor and that two or three hundred horse-power is required to drive additional motors, the power-factor of this circuit including the motor may be raised to 95 percent while delivering 1 000 k.v.a. This is shown graphically in Fig. 7.

Here—$AD=$ 1 000 k.v.a. in the generator load at 95 percent power-factor.

$AF=950$ kw is the true generator output at this power-factor.

$DF=312$ kw is the wattless component in the circuit.

$EG=BE-CE=402$ kw leading component in motor.

$EF=AF-AE=250$ kw true input of motor.

$GF=\sqrt{402^2+250^2}=475$ k.v.a. capacity of synchronous motor required. The loss in the motor at ten percent would be 47 kw and is represented by the line $EH$.

A 475 k.v.a. motor will therefore raise the power-factor of this 1 000 k.v.a. circuit to 95 percent and will in addition furnish 250 — 47 or 203 kw of mechanical power. If for example synchronous motors of this capacity cost $10 per k.v.a. delivered and erected, then since the 475 k.v.a. synchronous motor delivers 203 kw in mechanical power it is fair to charge only 475—203 or 272 k.v.a. to power-factor improvement, therefore $2 720 would be required to increase the capacity of this plant by 203 kw by raising the power-factor.

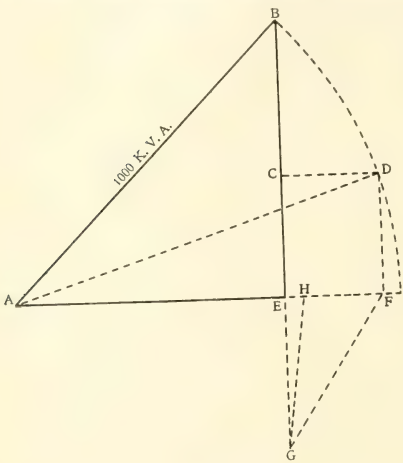


FIG. 7

If the capacity is increased by installing a new generator, engine, necessary piping, etc., the cost would be approximately $10 000 for a 203 k.v.a. generator outfit. In other words, a new generator outfit to increase the output of this plant 203 kw would cost 10 000—2 720, or $7 280 more than a 475 k.v.a. synchronous motor delivering 272 kw mechanical power.

Of course the larger the mechanical output of the synchronous motor the less amount is chargeable to improving the power-factor and the greater the saving of the synchronous motor outfit. The mechanical power obtained from the synchronous motor is taken in the form of current from the generator at a high power-factor, whereas if additional generator and induction motors are installed in place of a synchronous motor, additional lagging current is introduced into the circuit with its corresponding tendency to lower the power-factor.

SUMMARY

In some cases where the plants are small and there is no use for a large synchronous motor it is advisable to install generators

having a k.v.a. rating at the power-factor likely to be obtained. The erroneous practice, however, is to install generators rated at 100 percent power-factor and thus greatly cut down the available capacity of the plant. This is possibly largely due to the fact that a great many purchasers of electrical apparatus for small alternating-current plants do not understand or appreciate the question of power-factor and also that if a generator salesman bids on a generator rated on a 70 or 80 percent power-factor basis he will be likely to find it difficult to convince the purchaser that his generator is worth more than his competitors' who are advocating a generator with a 100 percent power-factor rating in order to get the selling price down. The result is that salesmen as a rule do not advocate large enough alternating-current generators for the engines or water wheels which are to drive them.

The more mechanical power that synchronous motors give out in addition to furnishing leading current, the more efficient will be the installation, and for this reason it is desirable to make them do as much mechanical work as the case under consideration will warrant.

It rarely pays to attempt to raise the power-factor by the use of synchronous motors to values higher than 90 to 95 percent.

Synchronous motors in order to keep down the drop in wiring should, of course, be installed near the end of the lines. If they are installed in the power house, they will, of course, reduce the load on the generator but will not improve the line conditions. They are not very efficient when connected to exciter generators in the power plant unless they can be made to furnish more mechanical power than that required for exciting. If the exciter generators, however, furnish current for other work than that required for excitation, for example, such as operating direct-current cranes and other variable speed motors about the plant, then large returns from the synchronous motor-driven exciter outfit may be obtained. The greater the mechanical out-put the larger the returns.

When induction motors are replaced by synchronous motors in order to improve the power-factor the exchanges should be made on the larger sizes so as to reduce to a minimum the number of synchronous motors required.

Rotary converters may be operated at leading current and made to assist in improving power-factor. Spare generators, which may be disconnected from their prime movers, may also be used as synchronous motors and floated on the line.

# THE USE OF INTER-POLES ON RAILWAY MOTORS*

CLARENCE RENSHAW

PROBABLY the most promising improvement in direct-current railway motors for many years is the introduction of the inter-pole motor. The commutation of high-voltage current in railway motors has always been a most difficult problem for the designers of such machinery to solve, and the care of commutators and brushes forms no small part of the duties of the mechanical and electrical force of a railway company. The larger the motors used, the higher the voltage, and the more difficult the service conditions, the greater is the importance of this matter. With large motors, flashing over from brush holder to brush holder or from brush holder to ground is sometimes experienced, and on a large system with great power capacity behind them, such flashes often cause considerable damage to motors and control and annoying delays to the service. Most commutator and brush troubles are due either directly or indirectly to sparking, and it is to correct them by correcting their cause that the inter-pole motor has been designed.

Sparking on a commutator bites away a small amount of copper and carbon at each spark, but does not affect the mica between segments. If the sparking is continued, the copper is soon eaten down, thus leaving the mica sticking up. This "high mica" in turn makes the sparking worse and causes a general roughening of the commutator, flattening of the bars, etc., with consequent rapid wear of the brushes, filling the motor with carbon and copper dust, and sometimes causing it to flash, ground, etc. Milling down the mica below the copper prevents some of this trouble, but does not go to the root of the matter.

In service a railway motor does not run continuously with power on, but the time that it is operating under load is varied by a certain amount of coasting and stopping. During this no-load running the roughening which has been caused by the action of the current is partly corrected by the scouring and polishing effect of the brushes without load. In many cases the scouring action predominates so that the commutators remain bright and clean and take on a good polish.

The action of the inter-pole motor in preventing sparking and

*From a paper read before the Street Railway Association of the State of New York, June 26, 1907.

thus greatly reducing the wear on commutator and brushes can best be understood by the aid of a few simple diagrams. In these a multiple-wound armature has been shown for the sake of simplicity and clearness, although on an actual motor a two-circuit winding would ordinarily be used.

In a motor without inter-poles, as shown in Fig. 1, there are three sets of magnetic fluxes produced; first, the lines *aa* due to the main field coils; second, the lines *bb* due to the current in the armature winding as a whole, and third, the leakage *cc* around each of the

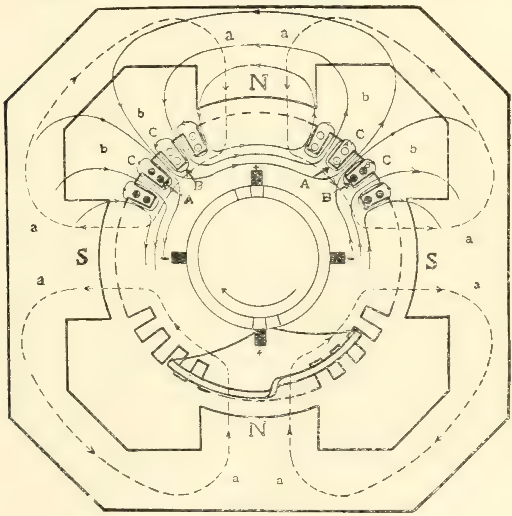



FIG. 1—MAGNETIC FLUX IN ORDINARY MOTOR

slots, due to the current in the conductors in that particular slot. The first set of lines may be regarded as the useful lines, and the second and third as incidental. It is to these last two that sparking is due. The coil *AA*, which is just about to have the current reversed in it, lies in such a position that it is not cutting the lines *aa*, and hence has no voltage generated in it from that source. It is, however, cutting the lines *bb*, so that it has a voltage generated in it by them. When the coil is short-circuited by the brush, this voltage causes a local current to flow across the face of the brush in addition to the line current, which greatly increases the amount of current

that the brush must carry. As the coil passes under the brush, also, from position *A* to position *B*, the current in the conductors in the slots *A* is stopped preparatory to being reversed, so that the leakage lines *cc* are also stopped preparatory to being reversed. This causes an inductive voltage to be created in the coil in addition to the voltage of rotation generated by the lines *bb*, and these two voltages added together produce a spark between commutator bar and brush.

In an inter-pole motor the inter-poles consist of thin poles, each carrying a coil, inserted into the frame between the main field poles

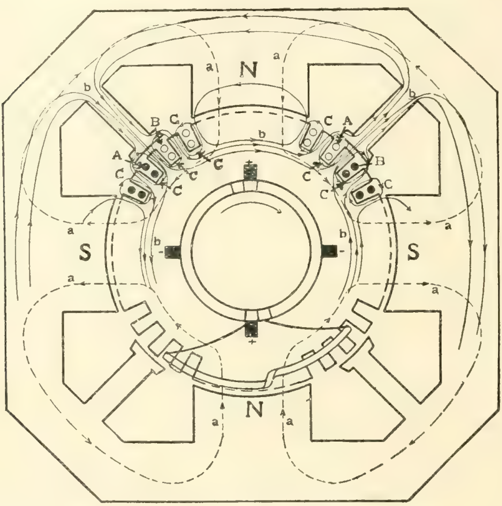



FIG. 2—EFFECT OF INTER-POLES WITHOUT COILS

and projecting down to the points on the armature at which the sides of the coils short-circuited by the brushes lie. If the inter-poles alone were used without any coil, as shown in Fig. 2, their effect would be to concentrate and increase the lines *bb* due to the armature magnetization, and also the lines *cc*, due to the leakage around the slots, owing to the additional iron in the path of those two sets of lines, and thus to raise the voltage in the short-circuited coil, and increase the sparking.

With coils on the inter-poles of a sufficient number of turns to just neutralize the armature magnetism, the effect of the lines *bb*

will be eliminated, as shown in Fig. 3, so that there will be no voltage generated in the short-circuited coil by its rotation, but the lines *cc*, due to leakage around the slots, will still remain, and the increase in these due to the presence of the inter-pole would ordinarily give a sufficiently high inductive voltage to more than offset the advantage gained by the neutralization of the rotation voltage.

If, however, a greater number of turns be wound on the inter-poles, so that their excitation overbalances the armature magnetiza-

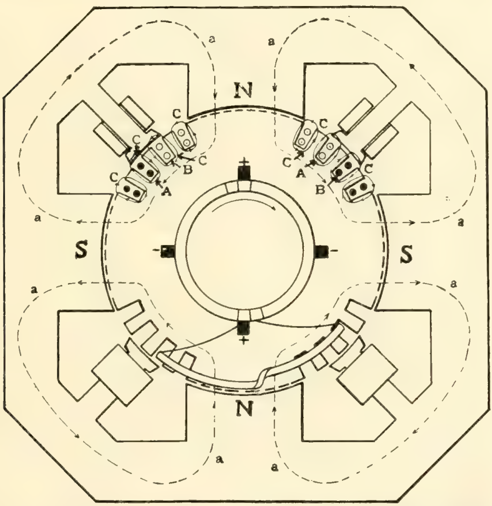



FIG. 3—INTER-POLE MOTOR WITH ARMATURE MAGNETIZATION JUST NEUTRALIZED

tion instead of merely neutralizing it and sets up a flux in the opposite direction, as shown in Fig. 4, this flux can be made of such a strength that the leakage lines around the coil which is being commutated will also be eliminated, so that practically all of the voltage in the short-circuited coil is neutralized and sparkless commutation is obtained. Since the inter-poles neutralize the active voltage in the short-circuited coils, they also eliminate the extra local current in the brushes and thus reduce the total current in the brushes to its minimum value, that is, to the line current. The elimination of sparking

and of local currents in the brushes reduces the wear on the commutator and prolongs the life of the brushes to a remarkable extent.

The inter pole winding is connected permanently in series with the armature winding, as shown in Fig. 5, forming the "armature circuit," and thus when the direction of rotation of the motor is reversed, the armature windings and inter-pole windings are reversed together as a unit.

Aside from the general reduction in wear of commutator and brushes, the inter-pole motor has many incidental advantages. A

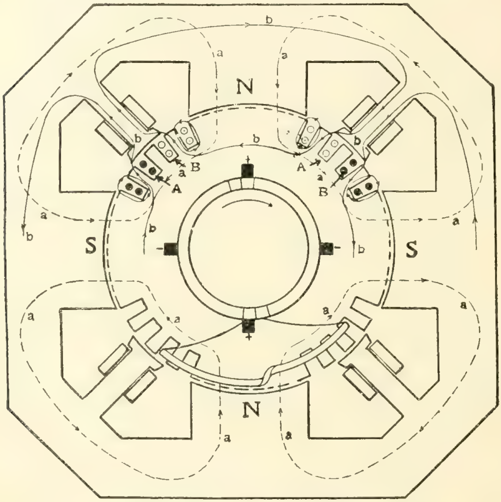



FIG. 4—MAGNETIC FLUX IN INTER-POLE MOTOR

properly designed motor of this type should run practically sparklessly from a load so light as to give treble the normal speed up to loads as heavy as double its ordinary one-hour rating. It should permit high voltages to be thrown on it, either at standstill or when running at high speeds, and its stability should be so great that it will commutate, without appreciable sparking, rushes of current which in the ordinary motor would invariably cause flashing. This great freedom from sparking and flashing makes the inter-pole motor especially well adapted for high-voltage service.

The use of the inter-pole increases the scope of the designer of

railway motors in many cases where limitations of speed and weight determine the design, and in general it permits of a somewhat lighter motor. It gives less advantage in small motors than in large ones, as the commutating conditions in such motors are not so serious a problem. However, its general advantages will doubtless extend its use to sizes as small as forty horse-power. Improving as it does those features of the railway motor which are universally acknowl-

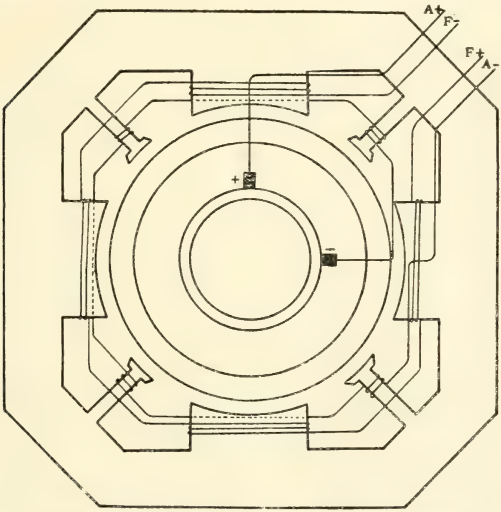



FIG. 5—METHOD OF CONNECTING INTER-POLE WINDINGS

edged to be in greatest need of improvement, the introduction of the inter-pole motor is an important step in electric railway development.

# RAILWAY SIGNALING—VI

## AUTOMATIC BLOCK SIGNALING

### DIRECT CURRENT

W. E. FOSTER

IN GENERAL, all signal circuits should be so arranged that a closed circuit is employed to give all safety indications and the operating battery should be at the end of the circuit farthest from the apparatus, in order that any crossed wires, broken wires or loss of power will cause a danger indication.

The simplest system of circuits is the polarized track circuit system shown in Figs. 1 and 2. Fig. 1 illustrates the application of the polarized system to an arrangement of signals where the home and distant arms are mounted on the same post. *H'* shows the wiring at the last signal of the system which would have no signal in advance and consequently no distant arm.

The home arm at this point is controlled through the contact of a neutral relay, *R*, connected to the track section in advance of it. The battery for the track section in the rear, instead of being connected direct to the rails, is carried through a pole changing circuit controller which is operated by the signal arm. With the arm in the stop position the pole changer would shift the battery from *AD-BC*, as shown in heavy lines, to *AC-BD* as shown in dotted lines, thus reversing the polarity of the battery as applied to the rails. *H* shows the wiring at all other signal locations. The home arm is controlled through contact *K* of relay *R*, the same as the home arm at *H.'* Contact *K* is called the neutral contact and is open or closed depending upon the amount of current flowing through the electro-magnet coils, and not by its polarity.

Contact K' is operated from another armature on the same relay. This armature is a permanent magnet which swings to either pole of the electro-magnet of the relay and thus shifts the contact K' whenever the polarity of the electro-magnet changes.

The distant arm is controlled through both *K* and *K'* so that the distant operating circuit will be closed whenever the home arm in advance has been cleared and the battery on the track is of the polarity shown. The distant arm is also controlled through a circuit controller operated by the home arm on the same post.

Fig. 2 shows the same scheme applied to an arrangement of signals where the home and distant arms are mounted on separate posts.

Fig. 3 shows a sectional view of a neutral type of relay.

Fig. 4 shows a sectional view of a combined neutral and polarized type of relay.

If it is assumed that there is a train in the section in advance of *H,'* the home arm at *H'* would be in the "stop" position and the battery would be reversed on the track section *HH.'*

At *H* the contact *K* would be closed and the contact *K'* would be open so that the home arm would be in the "proceed" posi-

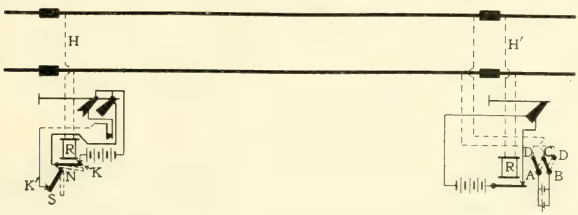



FIG. 1

tion and the distant arm would be in the "caution" position. When the train passes out of the section and the home arm at *H'* goes to the proceed position, thus reversing the polarity of the battery on the track section *HH'*, it may be noted that while the pole changer is shifting, i. e., for a fraction of a second, the relay at *H* would be de-energized and the contact *K* would open and then close. This opening of contact *K* would tend to release the home arm at *H* and return it to the "stop" position if provisions were not made to prevent

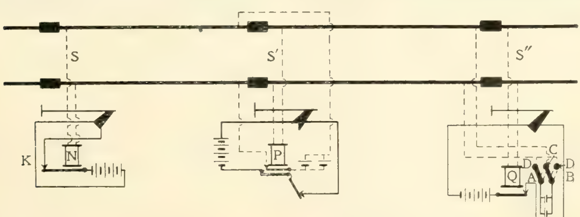



FIG. 2

it. This is prevented by applying a closed circuit inductive coil to the relay *R* or to the holding magnet of the signal, either of which will hold the signal arm clear momentarily by induction. If this slow releasing feature is applied to the relay, the contact *K* will remain closed long enough for the pole changer to shift. If it is ap-

plied to the holding magnet of the signal it will hold the arm long enough for the pole changer to shift in spite of the fact that $K$ may open for an instant. The latter scheme is usually employed.

Another automatic block signal system which is if anything better suited to meet all around conditions than the polarized system provides for the control of distant signals by line wires as shown in Fig. 5. The home arms are controlled directly from the track relays as previously described but the distant arm $a_1$ is controlled through an additional relay $R_2$ which in turn is controlled through line wires and a circuit controller (c) operated from the home arm $a$ in advance. The distant arm is also controlled by a circuit controller operated by the home arm $b$ on the same post. The line

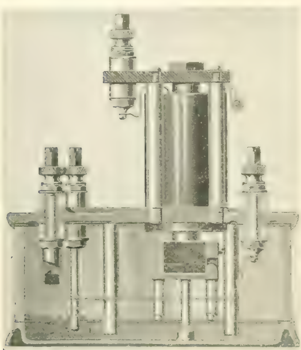


FIG. 3—SECTIONAL VIEW OF NEUTRAL TYPE RELAY

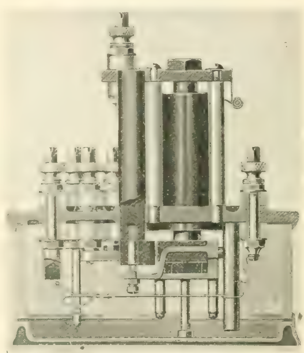


FIG. 4—SECTIONAL VIEW OF COMBINED NEUTRAL AND POLARIZED TYPE RELAY

wires have to be protected with lightning arresters but even then the distant arms are frequently out of service on account of lightning. For this reason other schemes which provide for the control of the home arms through line wires are objectionable and cause unnecessary delays to traffic.

Fig. 5 also shows what is done when the track section between signals is too long to operate as one section. It may be noted that the track circuit is relayed at the cut sections by a method somewhat similar to that employed in telegraph lines. Usually from 3 000 to 5 000 feet of track can be operated without a cut. The signal operating batteries $B$ and $B'$ each consist of 16 cells of caustic potash

primary battery, connected in series and housed in a receptacle placed sufficiently deep to prevent freezing; or they might each consist of five cells of storage battery in an iron case beneath the signal operating mechanism. The track batteries $B_2$-$B_3$ consist of two or three cells of gravity battery connected in multiple and placed in an iron chute below the frost level. One cell of storage battery with from one to two ohms resistance in series with it may be used instead. Fig. 6 shows a typical battery and relay shelter at a cut section. Storage batteries give the best results on both track and signal operating circuits, but their first cost is usually greater.

Fig. 7 shows the signal operating mechanism now almost exclusively used on the leading railroads. About 25 000 are in use. It consists primarily of a motor and an electric clutch or holding

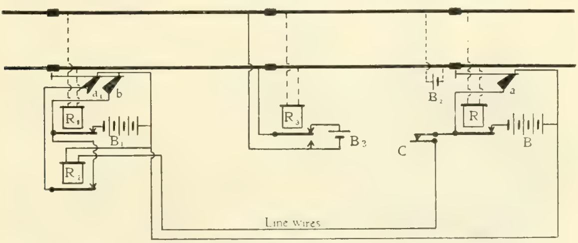



FIG. 5—DIAGRAM OF CONNECTIONS WHEN TRACK CIRCUIT RELAY IS USED

magnet, the latter being mounted on a compound lever to which the operating rod of the signal arm is attached near the center. This compound lever is pivoted near one end and the motor, through a train of gears, drives a chain carrying a trunion which engages with the free end of the lever and raises it when the operating current is applied to the motor and magnet. After the arm is raised the motor is automatically cut out and stopped by a friction brake. The end of the lever then drops back a little and rests on a catch where it is held, free from the motor gearing and chain, until the magnet is de-energized by the opening of the control relay. When the magnet is de-energized the lever arm drops down by gravity because the armature of the magnet releases the train of levers in the arm and thus releases the end of the arm from the catch. The fall of the lever arm is eased by means of the dash-pot connected outside the pivot end.

Fig. 7 shows a two arm movement, the lever arm at the front

being lifted to operate the home signal arm and the lever arm at the back being down with the distant signal arm in the "caution" position. Beneath the clutch, or slot magnet, as it is called, is the pole changer operated by the home signal lever arm.

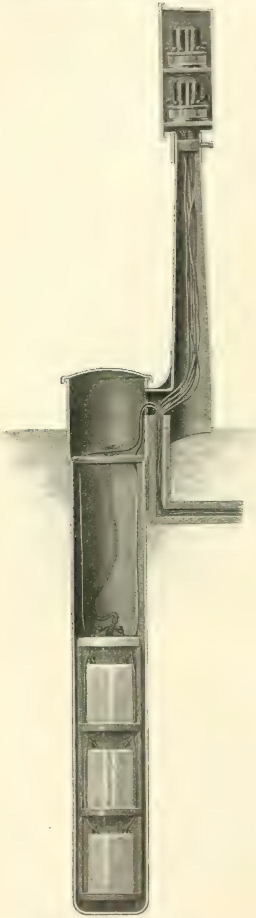


FIG. 6—SECTIONAL VIEW OF BATTERY AND RELAY SHELTER

The leverage is such that the armature of the slot magnet only has to hold up from one to three pounds, although the combined load of operating rod, signal arm and slot lever arm is over 100 pounds. The slot magnets are compound wound, a low resistance winding being in series with the motor and cut out with it, and a high resistance winding (500 to 2 000 ohms) being in multiple with the motor to hold the arm after the motor cuts out.

The operating voltage is usually about ten volts, the time required for operating one arm about six seconds, and the motor current about two amperes.

This mechanism is exceptionally free from friction, the armature of the slot magnet is far enough from the core so that it cannot be held by residual magnetism and the weight of all moving parts tends to restore the signal to the stop position as soon as the track relay cuts off the battery current.

The protection of switches in block signal territory has been left to the last in order that the main scheme might not be confusing. Each switch is insulated so that the track circuit passes through it unbroken. A circuit controller such as shown in Figs. 8 and 9 is

attached to the point of the switch and adjusted so that if the switch is open one-fourth of an inch the track circuit will be short-circuited as if by the presence of a train. For the guidance of trains coming out of a siding onto the signaled track, a switch indicator mounted on an iron post near the switch is employed. The switch indicator is usually so controlled that when a train is approaching

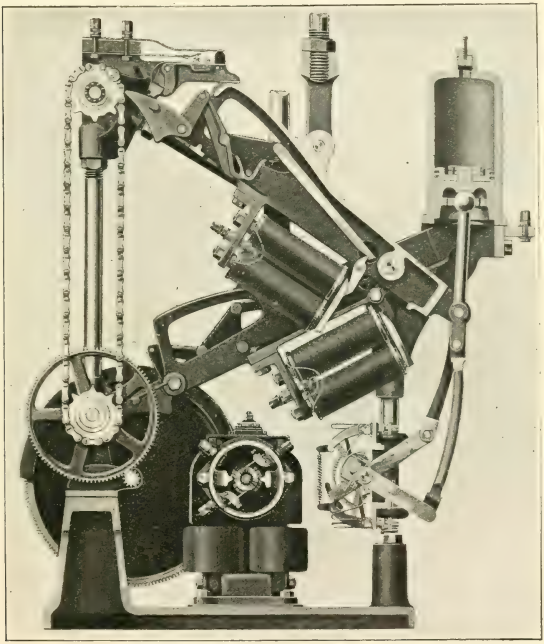


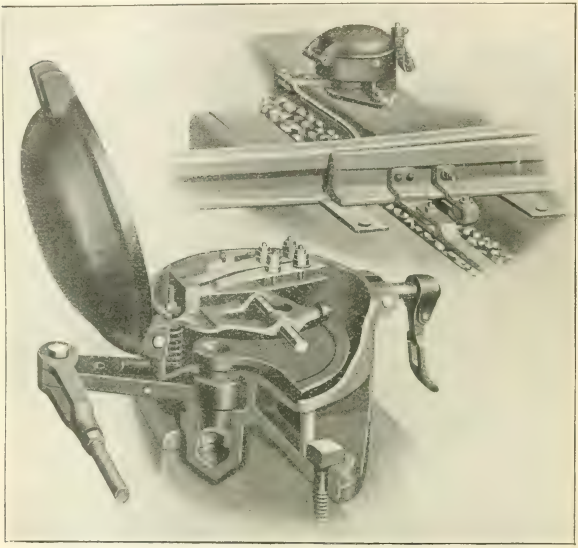
FIG. 7—ELECTRIC SIGNAL OPERATING MECHANISM

The right hand rod at the top connects with the home signal arm and the left hand rod connects with the distant signal arm. There is a second chain back of the one shown for operating the distant lever arm.

on the main track two blocks away the miniature semaphore is set to the "stop" position to warn the train in the siding not to open the switch. All sidings are made a part of the track circuit up to the

fouling point to protect trains on the main track from cars which may not clear it.

The average cost for an automatic block system using home and distant signals on the same post is from $750 to $1100 per block section, depending on the length of block, number of switches



FIGS. 8 AND 9—VIEW OF CIRCUIT CONTROLLER APPLIED TO SWITCH AND ALSO IN DETAIL

and method of signal control. The average cost of maintenance and operation of such a system is from $75 to $100 per two-arm signal per year.

# NEW STANDARDIZATION RULES OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

THE new Standardization Rules cover nearly thirty pages and include three hundred and sixty numbered paragraphs. Some of the salient features of the revision are as follows:

### MOTORS—SPEED CLASSIFICATION

Motors may, for convenience, be classified with reference to their speed characteristics as follows:

*a. Constant-Speed Motors,* in which the speed is either constant or does not materially vary; such as synchronous motors, induction motors with small slip, and ordinary direct-current shunt motors.

*b. Multi-Speed Motors* (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings.

*c. Adjustable-Speed Motors,* in which the speed can be varied gradually over a considerable range; but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of field variation.

*d. Varying-Speed Motors,* or motors in which the speed varies with the load, decreasing when the load increases; such as series motors.

### PERCENTAGE OF SATURATION

The percentage of saturation of a machine at any excitation may be found from its saturation curve of generated voltage as ordinates, against excitation as abscissas, by drawing a tangent to the curve at the ordinate corresponding to the assigned excitation, and extending the tangent to intercept the axis of ordinates drawn through the origin. The ratio of the intercept on this axis to the ordinate at the assigned excitation, when expressed in percentage, is the percentage of saturation and is independent of the scale selected for excitation and voltage.

This method of designating saturation was proposed in a communication to the Electrical World by Mr. H. S. Baker, a member of The Electric Club.

### INSULATION

The treatment of "Dielectric Strength" and high-voltage testing is rewritten and includes nearly fifty paragraphs. It covers the subject in a comprehensive and up-to-date manner, and is based upon the experience of those who are most familiar with tests of this kind.

The testing voltages for apparatus, the rated terminal voltage of which does not exceed 10 000 volts, is the same as formerly, but for higher pressures the test voltage is increased to double the normal rated voltage.

Under the heading "Methods of Testing", tests are divided into two kinds, as follows:

*Classes of Tests*—Tests for dielectric strength cover such a wide range in voltage that the apparatus, methods and precautions which are essential in certain cases do not apply to others. For convenience, the tests will be separated into two classes:

*Class 1*—This class includes all apparatus for which the test voltage does not exceed ten kilovolts, unless the apparatus is of very large static capacity, *e. g.*, a large cable system. This class also includes all apparatus of small static capacity, such as line insulators, switches and the like, for all test voltages.

*Method of Test for Class 1*—The test voltage is to be continuously applied for the prescribed inerval—(one minute, unless otherwise specified). The test voltage may be taken from a constant-potential source and applied directly to the apparatus to be tested, or it may be raised gradually as specified for tests under Class 2.

*Class 2*—This Class includes all apparatus not included in Class 1.

*Method of Test for Class 2*—The test voltage is to be raised to the required value smoothly and without sudden large increments and is then to be continuously applied for the prescribed interval—(one minute, unless otherwise specified), and then gradually decreased.

Conditions and precautions for Class 1 and Class 2—The following apply to all tests:—

The wave shape should be approximately sinusoidal and the apparatus in the testing circuits should not materially distort this wave.

The supply circuit should have ample current-supply capacity so that the charging current which may be taken by the apparatus under test will not materially alter the wave form nor materially affect the test voltage. The circuit should be free from accidental interruptions.

Resistance or inductance in series with the primary of a raising transformer for the purpose of controlling its voltage is liable seriously to affect the wave form, thereby causing the maximum value of the voltage to bear a different and unknown ratio to the root mean square value. This method of voltage adjustment is, therefore, in general, undesirable. It may be noted that if a resistance or inductance is employed to limit the current when burning out a fault, such resistance or inductance should be short-circuited during the regular voltage test.

The insulation under test should be in normal condition as to dryness and the temperature should when possible be that reached in normal service.

*Additional Conditions and Precautions for Class 2*—The following conditions and precautions, in addition to the foregoing, apply to tests of apparatus included in Class 2.

*Sudden Increment of Testing Voltage* on the apparatus under test should be avoided, particularly at high voltages and with apparatus having considerable capacity, as a momentarily excessive rise in testing voltage will result.

*Sudden Variations in Testing Voltage* of the circuit supplying the voltage during the test should be avoided as they are likely to set up injurious oscillation.

*Good Connections* in the circuits supplying the test voltage are essential in order to prevent injurious high frequency disturbances from being set up. When a heavy current is carried by a small water rheostat,

*Transformer Coils*—In high-tension transformers, the low-tension coil should preferably be connected to the core and to the ground when the high-tension test is being made in order to avoid the stress from low tension to core, which would otherwise result through condenser action. The various terminals of each winding of the high-tension transformer under test should be connected together during the test in order to prevent undue stress on the insulation between turns or sections of the winding in case the high-voltage test causes a breakdown.

The two instruments in common use for measuring the testing voltage (the spark gap and the voltmeter) are considered at some length and their respective characteristics and the precautions to be observed in their use are given with considerable detail. The voltage control necessary in many tests "may be secured in either of several ways, which, in order of preference, are as follows: 1—by generator field circuit; 2—by magnetic commutation; 3—by change in transformer ratio; 4—by resistance or choke coils". These methods are then taken up in detail.

### RISE OF TEMPERATURE

A simple method is given for determining the rise of temperature of a copper wire when the initial and final resistances are measured and the initial temperature is known.

The temperature rise may be determined either (1) by dividing the percentage increase of initial resistance by the temperature-coefficient for the initial temperature expressed in percent; or (2) by multiplying the increase in percent of the initial resistance by 238.1 plus the initial temperature in degrees C., and then dividing the product by 100.

The temperature coefficients from and at each degree between zero and fifty degrees Centigrade are given in the appendix. Several values taken from the table are as follows:

| Temperature | Coefficient | Temperature | Coefficient |
|---|---|---|---|
| 0 degrees | 0.42 percent | 25 degrees | 0.38 percent |
| 6 " | 0.41 " | 32 " | 0.37 " |
| 12 " | 0.40 " | 40 " | 0.36 " |
| 18 " | 0.39 " | 47 " | 0.35 " |

From this table it may be seen that at a temperature of 25 degrees the temperature coefficient is 0.38 percent per degree Centigrade. The resistance at a temperature above 25 degrees may be found by increasing the resistance at 25 degrees by an amount equal to the coefficient multiplied by the number of degrees elevation above 25 degrees. In the foregoing table the coefficients for intermediate temperatures may be found by interpolation, or the coefficient corresponding to the nearest temperature given in the table will give a result which is approximately correct.

A barometric pressure correction is given as follows:

*Barometric Pressure Correction*—When the barometric pressure differs greatly from the standard pressure of 760 mm. of mercury, as at high altitudes, a correction should be applied. In the absence of more accurate data, a correction of one percent of the observed rise in temperature for each ten mm. deviation from the 760 mm. standard is recommended. For example at a barometric pressure of 680 mm. the observed rise of temperature is to be reduced by $\frac{760-680}{10} = 8$ percent.

STANDARD VOLTAGES

An average voltage of 2 200 volts is recommended for primary distribution circuits, with step-down transformer ratios of 1:10 and 1:20. New paragraphs are then introduced as follows:

*Transmission Circuits*—In alternating-current constant-potential transmission circuits, the following average voltages are recommended:

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 600 | 11 000 | 22 000 | 33 000 | 44 000 | 66 000 | 88 000 |

*Transformer Ratio*—It is recommended that the standard transformer ratios should be such as to transform between the standard voltages above named. The ratio will, therefore, usually be an exact multiple of 5 or 10, *e. g.*, 2 200 to 11 000; 2 200 to 44 000.

RAILWAY MOTORS

An appendix devoted to railway motors is divided under two headings "Ratings" and "Selection of Motor for Specified Service". In an introductory note attention is called to the continual variation in the speed and torque usually developed by a motor in service and the impracticability of assigning a simple and definite rating which will indicate correctly the absolute capacity of a given motor or the relative capacity of different motors under service conditions. The nominal rating, or the horse-power output which a motor can give with a rise of temperature not exceeding 90 degrees at the commutator and 75 degrees at any other part after an hour's run on a test stand is a method of designating motors which is in common usage, though it is not a proper measure of service capacity.

The selection of a motor for a specified service involves,

*a.* Mechanical ability to develop the requisite torque and speeds as given by its speed-torque curve.

*b.* Ability to commutate successfully the current demanded.

*c.* Ability to operate in service without occasioning a temperature rise in any part which will endanger the life of the insulation.

It is recommended that running tests shall be made under actual conditions of service where practicable, or that an equivalent test be made under a typical run. Where it is not convenient to test motors under either of these conditions, recourse may be had to one of the following two methods of determining the temperature rise which are now in general use: First, "Method by Losses and Thermal Capacity Curves", and, second, "Method by Continuous Capacity of Motor". These methods are taken up in detail.

# STORAGE BATTERIES (Con'd.)

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16. *Floating Batteries*—In plants in which considerable voltage fluctuations are not objectionable, or are unavoidable, storage batteries are often used without any means for regulating them, simply as floating batteries. This allows the battery to be freely charged or discharged with the fluctuations of the load. This system is used in some electric railway sub-stations, and also in plants containing cranes and elevators. The number of cells is selected so that when the generators give approximately the average output of the station, the voltage at the bus-bars is equal to the e.m.f. of the battery; under such conditions no current flows in or out of the battery. When the load is below the average, the generator voltage is higher than that of the battery, and a charging current flows into the battery. When the generator is carrying a rather heavy load, its voltage drops below that of the battery, and the battery discharges into the line, helping the generators (or rotary converters, if it is a sub-station). With such an arrangement the generator load is more constant than without the battery. The battery is never entirely discharged or fully charged, but is maintained in a medium condition. Once every few weeks it is necessary to raise the generator voltage and to give the battery a thorough charging and even an overcharge in order to prevent the formation of lead sulphate.

It is evident that such a *floating* battery is more effective when the voltage fluctuations are large. The voltage at the end of the feeders varies much more than in the sub-station, on account of the ohmic drop in the feeders; therefore it is better to have a floating battery at the end of the line. The advantages are,—the average voltage being lower than in the sub-station, less cells are required; the fluctuations of the voltage being more pronounced, the battery is charged and discharged within wider limits; the load on the generators or rotary converters is steadier; there is a considerable saving in line copper, since the feeders have to carry the average current instead of the maximum current. The chief disadvantage of placing the battery at the end of the feeder is that extra room and attention is required outside the sub-station.

17. *Battery Boosters*—In addition to the cases described in §§ 12, 14 and 16 most large storage-battery plants are provided with

so-called boosters, or extra generators for regulating the charge (and sometimes also the discharge) of the batteries. The simplest combination is shown in Fig. 12; the booster *B* is driven by an ordinary shunt motor *M*. The armature of the booster is in series with the battery; the fields are separately excited across the bus-bars; *E* is the end-cell switch.

When the battery is discharging, the switch *S* is thrown up so that the booster is cut out of the circuit; the discharge is regulated by the end-cell switch *E*. For charging the battery the switch *S* is thrown down and the booster e.m.f. raised by means of the field rheostat *FR*; thus giving, together with the generator pressure, a voltage sufficient for charging. This voltage is regulated, as the charge progresses, by means of the same rheostat *FR*.

Instead of using an end-cell switch, the same booster may also be used for regulating the discharge of the battery. In this case

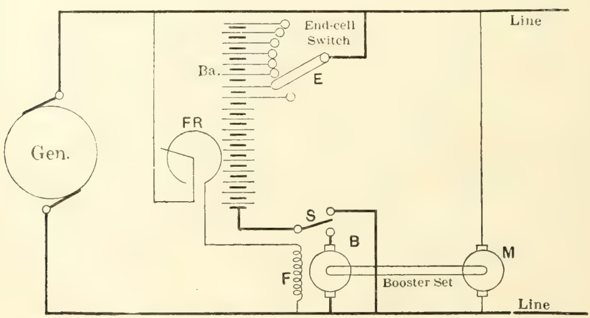


FIG. 12—BATTERY CHARGED BY A NON-AUTOMATIC BOOSTER, WITH DISCHARGE REGULATED BY THE END-CELL SWITCH E

a reversing switch must be connected into its field circuit, so that the direction of the induced e.m.f. may be changed.

Some companies connect the booster field across the battery and not across the line as in Fig. 12; there is not much difference in the two methods.

Shunt-excited boosters with hand regulation, as shown in Fig. 12, are satisfactory only in plants in which the load varies gradually and regularly, so that the battery can be charged and discharged during considerable periods of time. In railway service, where the load fluctuates within wide limits and where charge and discharge sometimes follow each other every few seconds, it becomes neces-

sary to have *automatic* boosters whose e.m.f. is added to or subtracted from that of the battery according to the magnitude of the load.

There are two types of automatic boosters used at present,—one in which the booster field is varied by the addition of compounding windings (Fig. 13); another in which the current in the shunt field is regulated by suitable relays (Figs. 15 and 18).

18. *Differential Booster*—This belongs to the first of the two types of automatic boosters mentioned above, and is shown in Fig. 13. It differs from the non-automatic booster shown in Fig. 12 in that the end-cell switch $E$ is omitted, and the booster is provided with an additional series-field winding $F_2$, which opposes the action of the winding $F_1$. At a certain average load $F_1$ and $F_2$ neutralize each other, and the booster e.m.f. is zero. At this load the generator

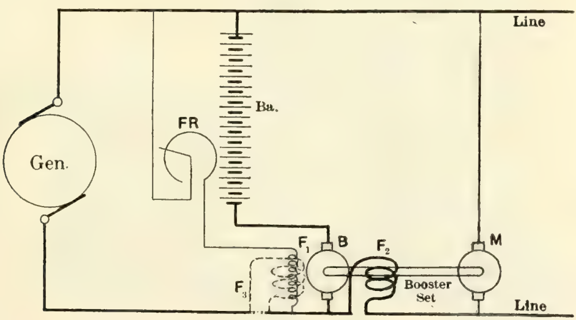


FIG. 13—AUTOMATIC DIFFERENTIAL BOOSTER

Charge and discharge of the battery are regulated by the series windings $F_2$ and $F_3$ so that the generator load remains practically constant.

voltage must be made equal to that of the battery so that the battery neither charges nor discharges. At a heavier load the action of $F_2$ is stronger than that of $F_1$, and the booster e.m.f. is added to that of the battery, assisting its discharge. On light loads the action of $F_1$ is stronger than that of $F_2$, and the booster tends to send a charging current into the battery. This action is entirely automatic, and the booster tends to maintain a constant load on the generators, the battery taking up the load fluctuations.

Experience shows, that in order to have this system work satisfactorily it is necessary to add a third field winding $F_3$ (shown by

dotted lines), acting in the same direction as $F_2$. This winding automatically corrects the voltage of the booster for the state of charge of the battery, as is explained below.

Suppose that the currents in the three field windings are so adjusted, that the booster e.m.f. is zero with the rated generator current and with the battery partly discharged. Then with the same load and with the battery fully charged, the battery tends to take more than its share of load, reducing the generator current. This

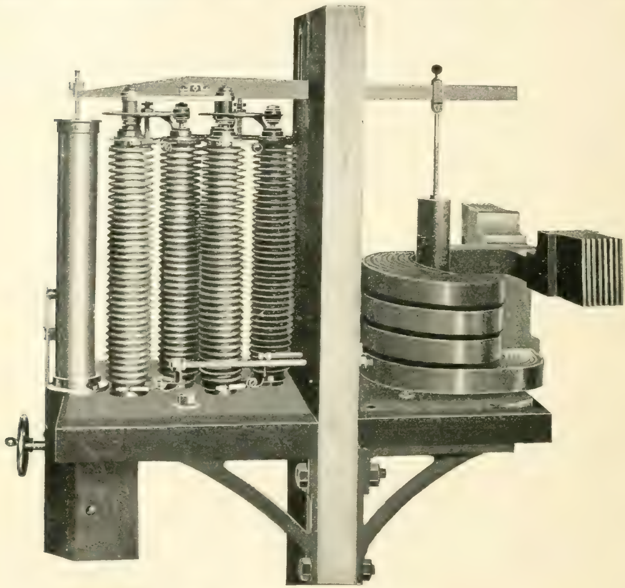

FIG. 14—CARBON-PILE REGULATOR

Made by the Electric Storage Battery Company. The generator current passes through the solenoid shown to the right; the plunger of the solenoid compresses, more or less, carbon discs shown to the left, and varies the booster excitation so as to keep the generator load constant.

reduces the current in the differential winding $F_3$, and gives a preponderance to the shunt field of the booster. An e.m.f. is produced in the booster such as to oppose the e.m.f. of the battery and to prevent it from discharging.

On the contrary when the battery is nearly discharged and does

not take its share of load, the generator becomes overloaded. Then an excessive current flows through $F_3$ and boosts the battery voltage helping its discharge. In this way the winding $F_3$ helps to keep the generator load constant.

19. *Carbon-Pile Booster Regulator*—One common drawback of automatic boosters provided with series fields, as shown in Fig. 13, is that the booster itself becomes quite large and expensive, since its frame has to accommodate three field windings. It has been sought, therefore, to have on the booster only the shunt winding, as in Fig. 12, and to provide *outside the booster* an additional device

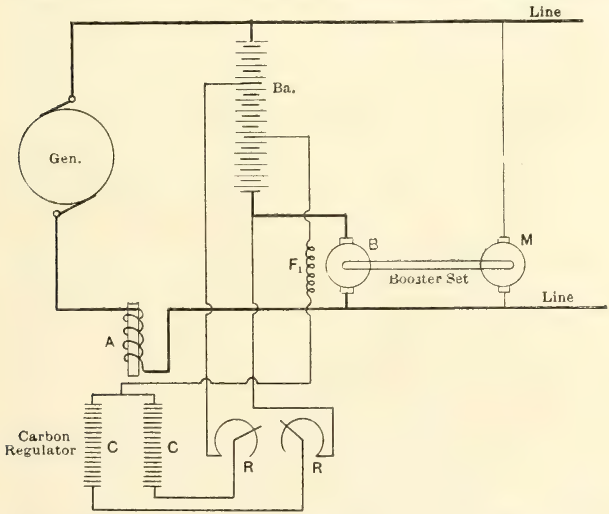


FIG. 15—ELECTRICAL CONNECTIONS OF A BOOSTER CONTROLLED BY THE CARBON-PILE REGULATOR SHOWN IN FIG. 14

that would automatically vary the magnitude and the direction of the current in this shunt winding, according to the load. A device of this kind is shown in Fig. 14; Fig. 15 shows the electrical principle upon which it is based. It is usually mounted on the main switchboard.

Generator current instead of passing through a series winding placed on the booster passes through a solenoid *A*. An iron core actuated by this solenoid compresses more or less, through a suitable leverage, two sets of columns *C C* consisting of carbon discs.

These carbon piles are connected to the booster field and to the battery as shown in Fig. 16. The resistance of the columns consists chiefly of the contact resistance between the discs, and therefore varies within wide limits with the pressure exerted by the core of the solenoid *A*.

With the normal value of the generator current the pressure on both piles is the same; their resistances are equal, and no current flows through the booster field $F_1$. The whole arrangement resembles the familiar Wheatstone bridge scheme, in which the booster field takes the place of a galvanometer. When the current is below or above normal one column is compressed more than the other, the bridge is not balanced, and a current flows through the booster field in one or the other direction, causing the battery either to charge or discharge. The arrangement is entirely automatic in its action, and takes the place of a booster with two or more field windings, tending to keep the generator current constant.

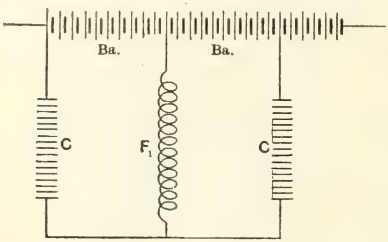

FIG. 16—A SIMPLIFIED DIAGRAM OF CONNECTIONS OF THE CARBON REGULATOR AND BOOSTER FIELD

In reality the connections are more complicated than those shown in Fig. 15. It would be too wasteful to have a current circulate all the time through the carbon columns, especially of such a magnitude as to be sufficient to energize the booster fields through unbalancing of resistances. Therefore, except in very small installations, *the carbon regulator actuates the field of a separate exciter, which in turn supplies current to the field of the booster.* The exciter being a much smaller machine than the booster itself, considerably less energy is lost in the regulator. The booster and the exciter are usually mounted on the same shaft and driven by a direct-connected motor.*

20. *Booster regulation by counter e.m.f.*—Another relay arrangement is shown in Fig. 17. Here the booster field $F_1$, is automatically regulated by a small counter-e.m.f. machine *C*. The

*The carbon-pile regulator is used by the Electric Storage Battery Co. chiefly in large railway plants.

field $F_2$ of this machine is excited by the main current as was the solenoid $A$ shown in Fig. 15. At a certain desired value of this current the counter e.m.f. of the machine $C$ can be made such that no current will flow through the booster field $F_1$. When the generator current is below this value, the booster field is excited in such a direction that the battery is charged, and *vice versa*.

Formerly the machine $C$ was direct-connected to the main booster set and driven by the same motor. Experience has shown, however, that the size of this machine can be considerably reduced driving it separately at a higher speed by a small motor $CM$. The size of the counter-e.m.f. set is still more reduced by introducing a second relay machine, as shown in Fig. 18. Moreover, this arrangement increases the sensitiveness of regulation and permits the coun-

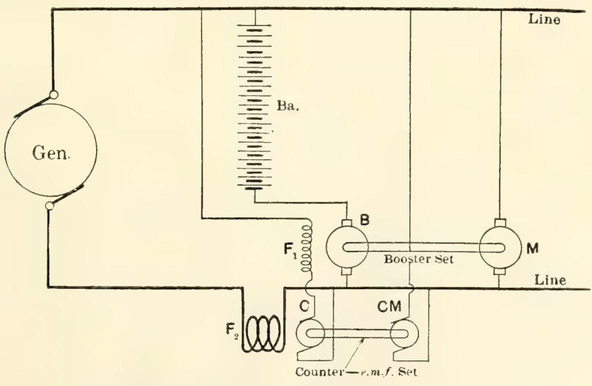


FIG. 17—A BOOSTER WHOSE FIELD IS REGULATED BY THE COUNTER—E.M.F. MACHINE C

The machine $C$ is excited by the generator current in $F_2$ and serves to maintain the generator current constant.

ter-e.m.f. sets to be made of the same standard size, with widely different sizes of batteries and boosters. The arrangement shown in Fig. 18 is the one actually used by the Gould Storage Battery Company.

The counter-e.m.f. machine $C$ instead of acting directly on the booster field, as in Fig. 17, acts on the field of a small exciter which in turn controls the booster field current. The armature of the counter-e.m.f. machine $C$ is connected in series with the exciter field, across the main busbars. When a normal current flows through the

main generator, and consequently through the field $F_2$, the voltage induced in the armature $C$ just balances the voltage across the busbars; consequently, no current flows through the exciter field, and the booster excitation is=zero. When the generator current is above the normal, the voltage in $C$ is higher than that across the busbars; the exciter field is energized in such a direction as to assist the battery to discharge. The opposite takes place when the generator current is below normal With proper relations the system works so as to keep the generator load practically constant.

In some cases, the counter-e.m.f. machine has an additional field winding connected across the line and giving a constant exci-

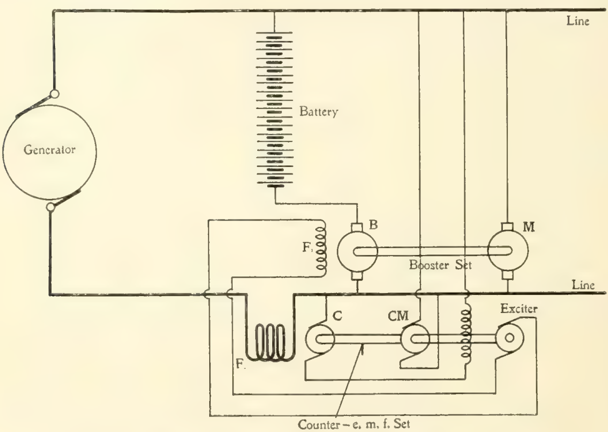


FIG. 18—A DEVELOPMENT OF THE SYSTEM SHOWN IN FIG. 17

The counter—e.m.f., machine C—actuates the field of the exciter Ex., which in turn controls the booster field (Gould Storage Battery Co.)

tation. The addition of this winding gives more flexibility to the system and permits of an adjustment for the desired performance of the battery. Further adjustment is made possible by using a rheostat in series or in parallel with the field winding $F_1$, and also by shunting the main series winding $F_2$ by adjustable resistances.

21. *Vibrating-contact booster regulator*—The success of Tirrill regulator for controlling voltage in generators led to the idea of applying the same principle to storage-battery regulation. Such a

battery regulator with vibrating platinum contacts was recently developed by the Westinghouse Electric & Manufacturing Company.

In common with the systems described in §§ 19 and 20, the booster field is energized either for charge or for discharge by a separate exciter. The exciter, which may be either direct-connected to the booster set or driven by a separate motor, has two equal and opposite field windings, connected in parallel across the main busbars. A third field winding *C* is connected across the armature terminals of the exciter and is its regular shunt winding. A platinum contact actuated by the main generator current short-circuits a resistance in series with either *A* or *B* and makes the action of one of the differential windings predominant. The shunt winding *C* immediately begins to build up the exciter current, which in turn effects the desired booster regulation. The tendency to over-regulate is checked by an electro-magnet which immediately opens the platinum contact.

The details of the regulator are as follows: An ammeter shunt is inserted into the generator circuit, so that the drop across the shunt is proportional to the generator current. A regular millivoltmeter movement, "No. 1," consisting of a moving coil, a permanent magnet and a spiral spring is connected across the shunt. Another similar movement "No. 2," is connected across the booster field; the arms of the two moving coils have two platinum tips which correspond to the main contacts in a Tirrill regulator. The closing or opening of these contacts causes an electro-magnet to short-circuit one or the other of the above mentioned resistances in series with the exciter fields.

Suppose the main contact between the two moving coils be closed; this closes the auxiliary contact which energizes the booster in such a direction as to help the battery to discharge. As soon as the exciter voltage begins to build up, the movement No. 2 opens the main contact. The auxiliary contact is also opened, and returns to its zero position in which it builds up the booster field in the opposite direction, i. e., for charging the battery. This increases the generator current above normal, the main contact is closed again, etc.

In reality, both contacts are vibrating continually, and in this way maintain the generator current practically constant.

For small adjustments, the spiral spring of the movement No. 1 may be tightened or loosened. For larger steps a series of resistances are provided with plugs by which the drop across the ammeter

shunt is increased or decreased. The movement No. 1 is also provided with a sensibility weight. By shifting it, the regulator may be over-compounded; this means that when the external load increases, the generator load also increases by a desired percentage.

22. *Storage batteries in alternating-current plants.* The question of equalizing load in alternating-current power plants by means of storage batteries is quite important. At present, batteries used in large railway and lighting plants are usually installed in sub-stations; each substation is thus regulated separately. A better economy could be obtained by having one large battery in the generator station, even though it would necessitate extra rotary converters or motor-generators between the line and the battery.

On fluctuating loads such batteries have to be controlled by automatic boosters with some relay between the main line and the booster field. The requirement in most cases would be to regulate for constant kw generator output; the current then varying only with the power-factor.

The problem is in rather an experimental stage, though it would seem that the systems of regulation described in §§ 19 to 21 may be made to operate successfully with alternating currents.

The Westinghouse regulators (§ 21) is particularly promising in this respect, as the only change would be to replace the ammeter shunt and the milli-voltmeter movement "No. 1" by any suitable wattmeter movement. The Gould arrangement shown in Fig. 18 has been successfully applied to an alternating-current plant by exciting the field $F_2$ from the main line through series transformers and a special rectifier. The device is adjusted so as to rectify only the working component of the current, thus making the effect of the booster depend on watts output and not on line amperes. A second rectifier, suitably displaced from the first, may be used for the wattless component of the current; this component when rectified may be used for compounding the rotary converter in order to correct for the power-factor of the load.

# SINGLE-PHASE VS. DIRECT-CURRENT RAILWAY OPERATION

## SEVERAL POINTS OF COMPARISON

MALCOLM MacLAREN

NO new discovery can be announced nor pioneer work of any character undertaken without creating controversy. It is naturally proper that new apparatus or new methods should be subjected to the severest scrutiny. However, it often happens that through lack of proper understanding of the new things or through insufficiency of correct data or error in methods of comparison or through preference arising from familiarity with established methods, incorrect and misleading conclusions are drawn.

Messrs. Parshall and Hobart in a recent book entitled "Electric Railway Engineering", which possesses much merit in its treatment of direct-current operation, have unfortunately failed to make an adequate presentation of the single-phase railway system.

Questions dealing with the relative merits of the several types of electric railway apparatus are of especial interest at the present time. It may be worth while, therefore, to take up some of the features of the single-phase system which have been inadequately presented, as they are matters which are liable to be misapprehended by others.

### COMPARATIVE WEIGHTS

A comparison is made (page 94) between direct-current and single-phase equipments for a 100-ton train where it is stated that with equal capacity of equipment direct current would provide seating capacity for 220 passengers and single phase 182 passengers; or for equal weight of equipment, direct current would be capable of developing 630 hp. and single phase 450 hp. The figures themselves do not check with actual conditions and the basis of comparisons is entirely erroneous.

The capacity of a train for a given service is not determined by the kind of current which is used, but by the conditions of traffic, and the power to be supplied to a car is determined by the service which it is desired to maintain, entirely irrespective of the system to be employed. The proper basis of comparison is to take cars of equal seating capacity and arranged for the same schedule speed. As approximating the conditions given by the authors, ref-

erence is made to the Indianapolis & Cincinnati Traction Company's single-phase cars, which weigh 48 short tons each complete with electrical equipment, or approximately 104 tons for a two-car train with load. Each car is equipped with four 100 hp., single-phase motors. The total weight of electrical equipment including supports for the apparatus and the car-wiring is 30 000 pounds per car instead of 33 600 pounds as allowed by the authors. Thus with less weight of equipment 800 hp. per train is obtained instead of 450 hp. If the same cars were equipped with direct-current motors for the same schedule speed, 90 hp. motors would be suitable. The total weight of quadruple equipment of such motors would be approximately 22 000 pounds. This checks closely with the authors' statement that the single-phase equipment is about forty percent heavier than a corresponding direct-current equipment; but the point of practical value to consider is the difference in the weight of the complete car. Owing to the lighter weight of the direct-current equipment, it would be possible to use slightly lighter trucks and under-framing for the car, which might save 2 000 pounds in this case. This gives a net saving of 10 000 pounds per car for direct current, or a total weight of 86 tons for a two-car train as against 96 tons for the single-phase train, or 94 tons for direct current and 104 tons for single-phase current, if a passenger load of say eight tons be added. These cars each seat 54 passengers, or 108 for the train, instead of 182 as given by the author in the assumed case.

IMPEDANCE

The figures giving the impedance per mile of circuit at different frequencies, (in the table on page 285) are somewhat higher than those obtained from measurements upon catenary line construction as installed on several roads in this country. Even using these figures the results (given below the table) are not apparent. The frequency upon which these figures are based is not stated, but assuming the worst case the impedance at 25 cycles for 100-pound rail is given at 0.775. The line current when transmitting 500 kw at 5 000 volts is 100 amperes, thus giving 77.5 volts drop per mile, or approximately 1.5 percent, instead of 13 percent as stated. When transmitting the same power at 3 000 volts the line current is 166 amperes, giving 128 volts drop, or approximately 4.3 percent instead of 30 percent.

TEMPERATURE RISE

It is claimed (on page 390) that the single-phase motor will

not dissipate its heat as readily as a direct-current motor of the same horse power on the one-hour basis on account of the greater weight of the single-phase motor and that therefore a comparison of the two types on the basis of the one-hour rating is too favorable to the single-phase motor. By comparing the results of actual test upon the two motors referred to above, it will be found that the single-phase motor will carry 100 hp for one hour on 25 cycles without exceeding a temperature rise of 75 degrees on the windings. The direct-current motor will carry 90 hp for one hour with the same temperature rise. The continuous rating with the same temperature rise, is 200 amperes at 235 volts on 25 cycles for the single-phase motor, or 51 brake horsepower, which is 51 percent of the one hour rating. For the direct-current motor the continuous rating with the temperature rise is 72 amperes at 500 volts, or 30 hp, which is approximately 44 percent of the one-hour rating; all the above on the basis of a shop test.

SINGLE-PHASE AND HIGH VOLTAGE DIRECT-CURRENT COMPARED

At the end of Chapter IX the authors compare a single-phase installation for a sixty-mile road, which was proposed by Mr. Lincoln*, with a similar installation using 1 350 volt direct current. In the case worked out by Mr. Lincoln twelve 41.3 ton cars were to be provided, each equipped with two 165-hp., 16 2/3 cycle single-phase motors. These were to operate at a schedule speed of 30 miles per hour under one-half hour headway, thus having eight cars on the line as a maximum. Power was to be furnished from a 3 000 volt overhead trolley through four sub-stations each containing one 350 kw transformer. The sub-stations were to be fed from the power house through a 20 000 volt transmission line. The power house was to contain three 525 kw, single-phase generators with their exciters and three 450 kw raising transformers. In the installation proposed by the authors the same number of cars was to be used and the same schedule speed maintained, each car weighing 36 tons and equipped with two 150 hp, 650-volt direct-current motors, connected permanently in series, and supplied with power from a 1 300-volt third rail. In order to avoid sub-stations it was proposed to provide two power stations each containing three 300 kw, 1 350-volt, direct-current generators coupled to slow-speed engines.

Assuming for a moment that the engineering features of the

*In his paper entitled "Interurban Electric Traction Systems." See Electrical World & Engineer, December 12, 1903.

two cases are on a fair basis, the conclusions reached are entirely misleading, as they compare the electrical apparatus only and no true comparison can be made without considering all parts of the installation affected by the system of electrification to be adopted. Two power houses required for direct-current would cost considerably more than the one power house for single phase; the six engines and their foundations required for driving the 300 kw generators would cost more than the engines and foundations for the three 525 kw single-phase generators and their exciters. The additional cost of boilers, condensers, steam piping and auxiliary steam equipment of the direct-current installation should all be taken into account in the comparison. The authors propose to balance these items against the sub-station buildings of a single-phase installation which actual costs on similar buildings show can be put up for from $1 000 to $1 500 each, or say $5 000 total. Furthermore, if the single-phase installation taken for comparison had been laid out in line with the present practice, the difference in favor of this system would have been even more pronounced. It will be noted that Mr. Lincoln's recommendations were made before any single-phase road had been installed in this country. At that time it seemed a conservative policy to recommend a comparatively low trolley voltage. Actual experience has now demonstrated that a trolley potential of 11 000 volts is entirely practicable. In the case under consideration 6 600 volts would seem to be sufficiently high. With this voltage it would only be necessary to furnish one sub-station, located about 36 miles from the power station. Under these conditions the power station would feed one-half the line direct. There would thus be some saving in power house equipment by cutting down the capacity of the raising transformers. The reduction in length of transmission line would effect a considerable saving and three sub-stations with their equipments would be eliminated at only a comparatively small increase in cost of the remaining sub-station owing to its greater capacity.

The authors' recommendation of a third rail for the high voltage direct-current installation is also to be questioned. Upon an interurban road of this character the only safe method of operation would be from an overhead trolley supported from a catenary, such as would be used for single phase, except that a lower voltage insulator might be employed. The difference in the cost of insulator would be offset by the heavier bonds required for direct current on account of greater rail current. Sufficient feeder capacity to keep

the maximum drop and loss in the line within the limits considered good practice in this country should also be provided with the direct-current installation.

Considered purely on the basis of cost, there is little or no choice between the third-rail and an overhead catenary construction with feeders. In order to cover the cost of a protected third rail and to allow for present labor and material costs, the author's figures for third-rail construction should be practically doubled. On this basis the first cost for third rail is considerably higher than the catenary construction and feeders, but the higher resistance of the overhead construction necessitates greater consumption of power, which offsets this difference.

The power taken by the single-phase car as given has been arbitrarily raised five percent above the figure given by Mr. Lincoln in order, it is said, to allow for car transformer losses. It has been found, however, that the run referred to can be made with an average power at the car equal to 73.9 kw, or say 74 kw including all the losses in the car.

The figures for the relative amount of power taken by the two systems should be revised in line with the above. Thus for direct current the average power at the car would be 77.5 kw, or 620 kw total for eight cars. The average efficiency of distribution from the power house to the car is 78 percent, which gives 795 kw at the power house. For single phase there would be 74 average kw per car, or 592 kw for eight cars. One-half of this is received direct from the power house with an average efficiency of 95.5 percent. For the other half the efficiency is approximately 84.2 percent divided as follows:

| | |
|---|---|
| Efficiency of trolley system | 95.2 |
| Efficiency of step-down transformers | 96.5 |
| Efficiency of transmission line | 95.0 |
| Efficiency of step-up transformers | 96.5 |

The average efficiency for the whole system is thus 89.7 which gives 661 total average kw at the power house and 735 k.v.a. with a power-factor of 90 percent.

The power house capacities which have been allowed by the authors are suitable for meeting the above conditions. It may be seen that, neglecting the spare units, 1 200 kw is provided for direct current and 1 050 kw for single phase. As the average loads upon the power house are 795 kw for direct current and 661 kw or 735 k.v.a.

for single phase, it is evident that the maximum load which occurs when several cars start simultaneously determines the power house capacity rather than the average conditions. The direct-current installation is hampered by the use of two power houses which are not interconnected, for with eight cars on the line each station must have capacity for taking care of at least five cars at a time in case of slight derangement of the schedule. Also on the theory of probabilities, a greater percentage of the cars may be started simultaneously with a total of five cars than with a total of eight cars. This is further accentuated by the lower efficiency of the direct-current installation and by the fact that the direct-current car takes from the trolley a maximum of 250 kw continuously for 30 seconds, while the single-phase car, although it takes a momentary maximum of 280 k.v.a., has an average maximum of 250 k.v.a. for only 15 seconds.

The excess of 15 percent in the generator capacity required for direct current over that required in the single-phase system is therefore seen to arise from the handicaps of the direct-current system in requiring more power at the car, in having the maximum load at the starting of cars for a larger period, in having greater transmission losses and in placing the generators in different power houses.

### COMPARATIVE COSTS

The first cost of installation chargeable to the electric system then becomes:—

#### POWER STATION

| *Direct Current* | |
|---|---|
| Six 300 kw, 1 350-volt, direct-current generators, complete with slow-speed engines | $96 000 |
| Switchboards and lightning protection .. .. .. .. .. .. | 4 000 |
| Additional sum chargeable to direct-current system for increased cost of buildings, boilers, condensers, steam piping, auxiliary steam equipment, etc. .. .. .. .. .. .. .. | 15 000 |
| | $115 000 |

| *Alternating Current* | |
|---|---|
| Three 525 kw, 15-cycle, single-phase, 6 600 volt generators with slow-speed engines.. | $61 500 |
| Three 300 kw 6 600 to 33-000 step-up transformers .. | 7 800 |
| Two 75 kw, 125-volt exciters with engines .. .. .. .. | 6 400 |
| Switchboard and lightning protection .. .. .. .. .. .. | 3 500 |
| | $79 200 |

#### HIGH TENSION LINE

| | |
|---|---|
| Thirty-six miles of 33 000-volt, single-phase transmission line, No. 4 B. & S. gauge (poles included with trolley system) .. .. .. .. | $19 800 |

SUB-STATIONS

| *Direct Current* | | *Alternating Current* | |
|---|---|---|---|
| | | Two 300 kw, 15-cycle, 33 000 to 6 600 step-down transformers | $5 200 |
| | | Switchboard and lightning protection | 1 250 |
| | | Building | 2 000 |
| | | | $8 450 |

LOW TENSION DISTRIBUTION SYSTEM

| | | | |
|---|---|---|---|
| Sixty-three miles overhead catenary trolley construction, complete with poles and rail bonding | $182 700 | Sixty-three miles of overhead catenary trolley construction, complete with poles and rail bonding | $182 700 |
| Sixty miles feeder | 60 000 | | |
| | $242 700 | | |

CAR EQUIPMENT

| | | | |
|---|---|---|---|
| Twelve two-motor 150 hp direct-current equipments complete; two motors connected permanently in series and arranged for rheostatic control | $68 400 | Twelve two-motor 165 hp 15-cycle, single-phase equipments | $96 000 |
| Total | $426 100 | | $386 150 |

OPERATING EXPENSES

The authors' estimate for yearly operating expenses should be modified in line with the above first cost. The total output from the power house and the cost of maintenance of equipment can best be considered upon a car mileage basis. The figures given above for average kw at the power house are based upon operating eight cars simultaneously at a schedule speed of 30 miles per hour, from which it follows that 3.31 kw-hr, per car mile will be required at the power house for direct current and 2.76 kw-hr. per car mile for single phase. On a line of this character it should be possible to obtain an average mileage throughout the year equal to about 200 car miles per day for each of twelve equipments. This gives a total yearly car mileage of 876 000, and a total output from the power house of 2 900 000 kw-hr for direct current and 2 420 000 kw-hr for single phase. Three-fourths of a cent per car mile is a fair figure to use for maintenance and repairs of direct-current car equipment. This is a little higher than the average of figures which have been published showing actual costs of similar 600 volt equipments, but some allowance should be made for higher maintenance charge on account

of the higher voltage and the more frequent inspection and cleaning which would be required with such equipments. A liberal allowance for single-phase equipments would be at the rate of one cent per car mile.

The transformers in the sub-station would not be artificially cooled as stated (on page 423) and actual experience has demonstrated that no appreciable expense is chargeable to the single-phase system for attendance and inspection of sub-stations using transformers of this capacity. The item charged against the single-phase system in the authors' estimate of operating expense on account of sub-station attendance should therefore be omitted. The estimate of yearly operating expenses would then become:

*Direct Current*

| | |
|---|---|
| Eight men at power house, two shifts, average wage $75 00 per month .. .. .. .. | $14 400 |
| Fuel, water, oil, etc., at 0.6c per kw-hr, 2 900 000 kw-hr .. | 17 400 |
| Repairs and maintenance of power house equipment (4 percent of cost) .. .. .. .. | 4 000 |
| Repairs and maintenance of trolley system (5 percent of cost) .. .. .. .. .. .. .. | 9 135 |
| Repairs and maintenance of feeders (one percent of cost) | 608 |
| Repairs and maintenance of car equipment, 876 000 car miles per year, at ¾ cent .. | 6 570 |
| Total .. .. .. .. .. .. | $52 113 |

*Alternating Current*

| | |
|---|---|
| Five men at power house two shifts, average wage $75 00 per month .. .. .. .. | $ 9 000 |
| Fuel, water, oil, etc., at 0.5c per kw-hr, 2 420 000 kw-hr .. | 12 100 |
| Repairs and maintenance of power house equipment (3 percent of cost) .. .. .. .. | 2 376 |
| Repairs and maintenance of transmission line (3 percent of cost) .. .. .. .. .. .. | 594 |
| Repairs and maintenance of sub-station equipment (3 percent of cost) .. .. .. .. .. | 193 |
| Repairs and maintenance of trolley system (5 percent of cost) .. .. .. .. .. .. .. | 9 135 |
| Repairs and maintenance of car equipment, 876 000 car miles, at one cent.. .. .. .. | 8 760 |
| Total .. .. .. .. .. .. | $42 158 |

From the above it appears that in this instance the single-phase system figures out cheaper than direct-current both in first cost and in operating expenses. When these figures are considered in conjunction with the fact that most of the single-phase lines already installed in this country are being rapidly extended, in some cases even replacing existing direct-current lines, and when engineers throughout the country are recommending single-phase for important installations after a careful study of the lines now in operation, it would seem that there is little danger of an early fulfillment of the authors' gloomy prophecies regarding the fate of the single-phase system.

# THE ELECTROLYTIC LIGHTNING ARRESTER

R. P. JACKSON

THE most recent development in devices designed to protect electrical apparatus from over-voltage due to lightning or other sources of disturbance is the electrolytic or aluminum cell arrester.

It has long been known that an electrolytic cell made up of two plates one of which is aluminum and the other carbon or some metal other than aluminum combined with a suitable electrolyte, possesses peculiar assymmetrical characteristics. Current will flow

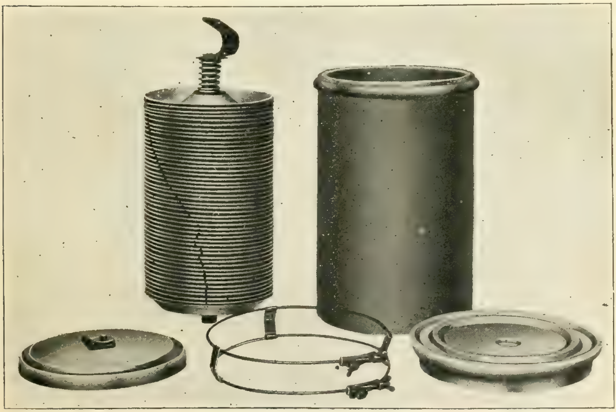

FIG. 1—PARTS OF 50 TRAY ELECTROLYTIC LIGHTNING ARRESTER UNIT

freely in one direction through such a cell while in the opposite direction but a very small current can be produced until the applied voltage reaches a certain value. After such voltage has been exceeded, however, the current increases much more rapidly than the impressed e.m.f. would indicate according to Ohm's law. It was known also that the seat of this peculiar action was in a very thin dielectric film on the surface of the aluminum plate. If both plates were made of aluminum a device was formed which had an action

quite analagous to that of the safety valve on a steam boiler in that little or no current, either alternating or continuous, would pass so long as the electrical pressure was kept below the critical value. If however, the pressure exceeded this value a very large current would follow which would cease to flow as soon as the voltage or electrical pressure resumed its original lower value.

Such a characteristic is an ideal one for protecting electric circuits against over-voltage and its attendant dangers. The present

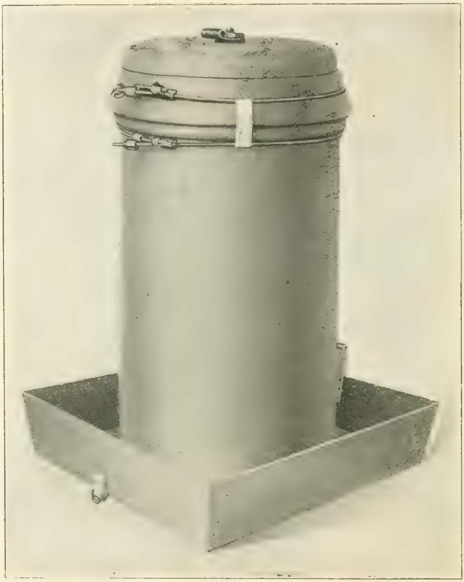

FIG. 2—SINGLE UNIT ARRESTER FOR 13 500-VOLT ALTERNATING-CURRENT CIRCUIT

electrolytic lightning arrester represents a commercial form of the above device as adapted for use on circuits of from 4 000 to 60 000 volts. With present known and commercial electrolytes about 400 volts represents the maximum which the film will sustain, so it is necessary to use a large number of such cells in series. Practically, on alternating-current circuits, it is necessary to operate the cells

at from 250 to 280 volts each to allow for the maximum of the e.m.f. wave.

The simplest form in which a large number of plates can be arranged in series and yet not have a path through the electrolyte from the first to the last plate is to assemble them in tray form so that one may rest within another, insulated from each other, but all containing the electrolyte. Fig. 1 shows how this is accomplished in the electrolytic lightning arrester. A tray unit built up in this form will withstand an effective voltage of 13 500 volts with a suitable margin of safety. The whole is enclosed in a stoneware jar for mechanical support and protection and each jar is provided with a suitable top so that one jar may be placed upon another for higher voltages than one unit will sustain. The electrolyte being poured in at the top of the jar fills each tray in succession from the top down and the surplus runs out at the bottom. Transformer oil may then be poured in which follows the electrolyte and forms a film of oil over all the exposed surfaces. This covering of oil prevents the solution from coming in contact with the air and thus practically obviates all evaporation under normal conditions of operation.

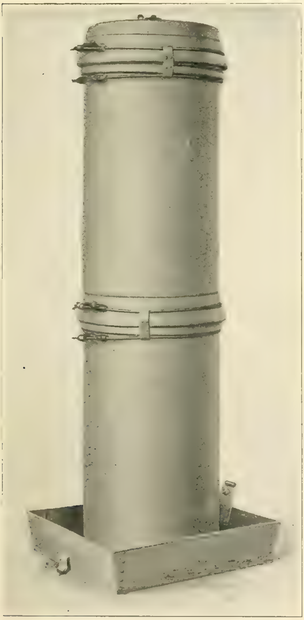

FIG. 3—TWO UNIT ARRESTER FOR 27 000-VOLT ALTERNATING-CURRENT CIRCUIT

Fig. 2 shows a single unit complete and Fig. 3 shows two units in form suitable for 27 000 volts. If connected directly to the line the slight leakage current will cause considerable heat which will evaporate the solution and soon damage the plates. If, however, a gap is placed in series of such a nature as to have some ability to suppress an arc, such a gap may be set very close to the break down value at the operating potential. In com-

mercial apparatus for potentials above 13 000 volts this gap takes the form of two diverging horns similar to that commonly known as the "horn arrester".

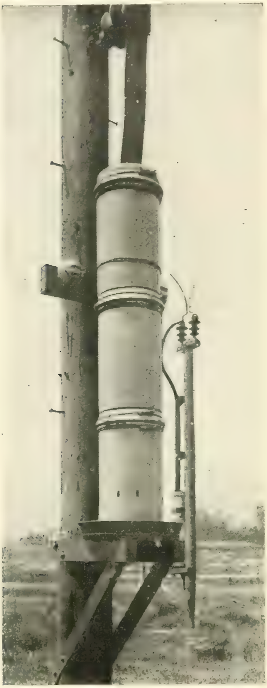

FIG. 4—ELECTROLYTIC LIGHTNING ARRESTERS

In service on 60 000-volt grounded neutral transmission line.

When thus arranged in series with a suitable "horn" air gap the electrolytic lightning arrester has all of the qualities of a safety valve as applied to electric circuits. At the ordinary operating potential it takes no current whatever, but as soon as any abnormally high potential surge or wave appears it permits, through its freedom of discharge, a sufficient flow of energy to maintain the potential of the circuit at practically the value at which the device begins to take current, i. e., to discharge. As soon as such a wave has passed, however, the arrester at once ceases to take current. Moreover, such a very small power current is taken during discharge that the other parts of the circuit are not disturbed in any way as in the case with arresters which at the time of discharge take a large power current.

From the present data it would seem that some form of the electrolytic lightning arrester represents about the limit of effectiveness attainable in such devices so long as dependence is placed on a single set of apparatus in the station to protect against all disturbances.

# PRINCIPAL DIMENSIONS AND DATA OF POWER STATIONS, SUB-STATIONS AND TRANSMISSION SYSTEM OF THE INTERBOROUGH RAPID TRANSIT COMPANY

Compiled by H. G. Stott, Superintendent Motive Power

## POWER STATIONS

| | 74TH STREET STATION | 59TH STREET STATION |
|---|---|---|
| PROPERTY | | |
| Dimensions | 559 ft. 6 15/16 in. by 204 ft. 4 in. (mean) | 950 ft. by 200 ft. 10 in. |
| Area | 114 340 sq. ft. | 190 792 sq. ft. |
| BUILDING | | |
| Dimensions | 404 ft. 7 11/16 in. by 204 ft. 4 in. (average) | 693 ft. 9¾ in. by 200 ft. 10 in. |
| BOILER ROOMS | | |
| Dimensions | 104 ft. by 407 ft. each | 83 ft. 1 in. by 693 ft. 9¾ in. |
| Total area | 84 864 sq. ft. | 57 644 sq. ft. |
| ELEVATIONS | | |
| Basement | 4 ft. 6 in. | 3 ft. 3 in. |
| First boiler room floor | 16 ft. 0 in. | 17 ft. 9 in |
| Water tenders platform | ........ | 25 ft. 9 in. |
| Platform over boilers | ........ | 40 ft. 4½ in. |
| Second boiler room floor | 40 ft. | ........ |
| Economizer floor | ........ | 54 ft. 9 in. |
| Coal bunkers (bottom) | 72 ft. 6 in. | 70 ft. 4 in. |
| Coal bunkers (top) | 103 ft. 0 in. | 96 ft. 4 in. |
| Coal conveyors | 114 ft. | 111 ft. 0 in. |
| Roof | 132 ft. | 126 ft. 0 in. |
| ENGINE ROOM | | |
| Dimensions | 93 ft. by 396 ft. | 117 ft. 9 in. by 693 ft. 9¾ in. |
| ELEVATIONS | | |
| Basement | 4 ft. 6 in. | 3 ft. 3 in. |
| Cable mezzanine | ........ | 13 ft. 9 in. |
| Engine room floor | 26 ft. 0 in. | 25 ft. 9 in. |
| Steam-pipe gallery | ........ | 40 ft. 4½ in. |
| Cable gallery | 41 ft. 0 in. | ........ |
| Switchboard gallery | 49 ft. | 54 ft. 9 in. |
| Bus bar gallery | 61 ft. 3 in. | ........ |
| Crane rail girder | 73 ft. 6 in. | 90 ft. 4 in. |
| Roof | 132 ft. | 127 ft. 0 in |
| STACKS | | |
| Number and type | 4 :Custodis | 5 :Custodis |
| Height above foundations | 278 ft 0 in. | 162 ft. |
| Height above lower grate | 261 ft. | 218 ft. |
| Height above datum | 282 ft. 6 in. | 241 ft. 1⅛ in. |
| Internal diameter (bottom) | 18 ft. | 16 ft. |
| Internal diameter (top) | 17 ft. | 15 ft. |
| Lining | Radial fire brick to elev. of 77 ft. 6 in. | Radial fire brick 28 ft. from base |

| | 74TH STREET STATION | 59TH STREET STATION |
|---|---|---|
| WATER TUNNELS | | |
| Intake | 8 ft. 6 in. by 12 ft. 3 in. | 8 ft. 6 in. by 10 ft. |
| Outlet | 5 ft. by 12 ft. 3 in. | 8 ft. by 10 ft. |
| CRANES | | |
| Equipment | One 50-ton; 15 ton auxiliary | One 50-ton hoist (2) with one 10-ton auxiliary<br>One 25-ton; 5-ton auxiliary |
| Span | 78 ft. | 74 ft. 4 in. |
| COAL AND ASH HANDLING MACHINERY | | |
| Hoisting towers | (a) Mead, Morrison, steam; fixed, 1 ton bucket; 150 tons per hour<br>(b) Link bolt steam movable, 1½ ton bucket; 200 tons per hour | (a) Mead, Morrison, steam; movable 1½ ton bucket; 200 tons per hour<br>(b) Robins Electric, fixed, 1-ton bucket; 150 tons per hour |
| Conveyors | (a) Overlapping bucket conveyor, motor driven<br>(b) Monabar; V bucket and 30 in. belt, motor driven | (a) 30 in. Robins belt, motor driven<br>(b) 30 in. Robins belt, motor driven to 20 in. Robins belt, motor driven to V-bucket, double chain elevator<br>(a) and (b) to two 20 in. Robins belts |
| Ash handling | Trolley industrial system to bucket conveyor | Storage battery industrial system to two overlapping bucket conveyors |
| Total lift (coal) | 114 ft. | 111 ft. |
| Total carry (max.) | 500 ft. | 1 450 ft. |
| COAL BUNKERS | | |
| Number | 3 | 7 |
| Capacity (total) | 7 500 | 14 000 |
| BOILERS | | |
| Type | B. & W. | B. & W. |
| Number | 64-520 b. h. p. 6-600 b. h. p. in two tiers | 60-600 b. h. p. in one tier |
| Heating surface per boiler | 5 200 sq. ft. and 6 008 sq. ft. | 6 008 sq. ft. |
| Working pressure | 160 lbs. | 200 lbs. |
| Tubes | 64 boilers; 12 by 21<br>6 boilers; 14 by 21 | 14 by 21 |
| Diameter tubes | 4 in. (No. 10 gauge) | 4 in. (No. 10 gauge) |
| Drums | 3-42 in. diameter | 3-42 in. diameter |
| Grates | Roney Stokers | 42 boilers each having 1-150 in. Roney Stoker front<br>18 boilers each having 1-150 in. Roney Stoker front and 1-120 in. rear |
| Grate area | 94 and 111.8 | 111.8 and 89.44 |
| Draught | Natural | Natural |
| Superheaters | ........................ | 4 Foster 900 sq. ft. each; 8 B. & W. 768 square feet each (in boilers) |

| | 74TH STREET STATION | 59TH STREET STATION |
|---|---|---|
| FEED WATER | | |
| Pumps | 8 Electrically driven single acting triplex 1 steam driven | 9 vertical compound duplex steam 12 in, 17 in. by 15 in. |
| Capacity | 65 h. p. | 104 000 lbs. per hour; 225 lb. head |
| Storage | 4 tanks, 24 000 gals. each | 8 tanks, 22 000 gals. each. |
| ECONOMIZERS | | |
| Number and type | 16—Green | 20 Sturtevant |
| Total heating surface | 98 304 | 152 880 |
| FEED WATER HEATERS | | |
| Number | 1 | 11 open Cochrane |
| Total heating surface | 600 | |
| ENGINES | | |
| Number and type | 8-A. C. Co. combined horizontal and vertical | 9-A. C. Co. combined horizontal and vertical |
| Height (above floor) | 35 ft. 1 in. | 34 ft. 6 in. |
| Floor space | 2 000 sq. ft. | 2 000 sq. ft. |
| Nominal rating | 8 000 i. h. p. | 7 500 i. h. p. |
| Cylinders (dia.) | 44 in., 88 in. | 42 in., 86 in. |
| Stroke | 60 in. | 60 in. |
| Speed | 75 r. p. m. | 75 r. p. m. |
| Crank angle | 135 degrees | 135 degrees |
| Steam pressure | 160 lbs. | 200 lb. |
| Valves | Corliss | H. P.—Poppet L. P.—Corliss |
| Cylinder ratio | 1:4 | 1:4.2 |
| Number cranks | 2 | 2 |
| Dia. piston rods | 8 in. | H. P.-9 in, L. P. 10 in. |
| Length connecting rod | 13 ft. 6 in. | 13 ft. 9 in. |
| Crank pins | 18 in. by 18 in. | 20 in. by 18 in. |
| Wrist pins | 12 in. by 12 in. | 13 in. by 13 in. |
| Shaft, length | 25 ft. 3⅛ in. | 25 ft. 3⅛ in. |
| Shaft, max. diameter | 37 in. | 37 in. |
| Shaft, bore | 16 in. | 16 in. |
| Shaft, bearings | 34 in. by 60 in. | 34 in. by 60 in. |
| Diameter revolving field | 32 ft. | 32 ft. |
| Weight " | 370 000 lb. | 370 000 lb. |
| Weight on bearings | 439 000 lb. | 439 000 lb. |
| Governors | Pendulum power | Pendulum power |
| CONDENSERS (ENGINE) | | |
| Number and type | 8-barometric tube | 9-barometric tube |
| Circulating pumps | 8 centrifugal; Ball high speed engines | Alberger vertical double acting compound steam |
| Size | 14 in. by 14 in. | 14 in., 20 in. by 30 in. |
| Dry air pumps | 1-Double acting, 2-cylinder motor-driven, 24 by 12 | |
| Dry vacuum pumps | | 8 Separate vertical Corliss, steam end, 8 by 24; air, 18 by 24; 80 r. p. m. |
| Air compressors | 1-steam single stage 12 by 12 by 12 Smith-Vaile | 2-steam duplex 2 stage 8 by 14, 8 by 8, L.D.G. Co. |
| STEAM PIPING | | |
| Arrangement | 8 in. from boilers to two 18 in. C. I. headers to two 15 in. downtakes to engine cross connections by two 15 in. lines | 9 in. from boilers to 18 in. headers (6 boilers) to two 15 in. lines to separators, to 15 in. to engine. 3 12 in. equalizers connecting 18 in. headers. |

| | 74TH STREET STATION | 59TH STREET STATION |
|---|---|---|
| OIL SYSTEM | | |
| Type | Gravity-ring system 4 in. duplicate mains | Gravity-ring system 4 in. duplicate mains |
| Pressure at bearings | 15 lb. | 25 lb. |
| Capacity elevated tanks | 7 000 gals | 7 000 gals. |
| Capacity filtering tanks | 13 000 gals. | 13 000 gals. |
| Size and number filter bags | 1 200—3 in. by 10 in. | 1 200—3 in. by 10 in. |
| REFRIGERATORS | | |
| Description | 1-5½ by 10 double-acting motor-driven ammonia compressor (5 tons 24 hours) | 1 5½ by 10 double acting motor-driven ammonia compressor (5 tons 24 hours) |
| TURBO-GENERATORS | | |
| Type | 1 Westinghouse — Parsons | 3 Westinghouse — Parsons |
| Capacity, rated each | 5 500 kw. | 1 250 kw. |
| Overload, rated each | 50 per cent. | 50 per cent. |
| Speed, r. p. m. | 750 | 1 200 |
| Steam pressure | 160 lb. | 200 lb. |
| Stages | 2 | 2 |
| Governor | Fly-ball throttling | Fly-ball throttling |
| Space required (above floor) | 47 ft. 3 in. by 16 ft. 0 in. by 14 ft. 0 in. high | 43 ft. 6 in. by 7 ft. 8 in. by 7 ft. 6 in. high |
| Cycles per second | 25 | 60 |
| Phases | 3 | 3 |
| Amperes, per phase | 289 | 66 |
| Volts | 11 000 | 11 000 |
| Armature connected | Y | Y |
| Poles | 4 | 6 |
| Amperes in field | 100 | 50 |
| TURBINE CONDENSERS | | |
| Number and type | 2 surface, A. C. Co. | 3 surface, Alberger |
| Cooling surface, each | 8 040 sq. ft. each | 4 500 sq. ft. |
| Pumps | 2-combined air and hotwell | 2-two stage, dry air 3 duplex hotwell pumps |
| Circulating pump | 2-16 in. centrifugal Westinghouse compound engine, 9 in., 15 in by 9 in. | 1-16 in. centrifugal Westinghouse compound engine, 9 in., 15 in. by 9 in. |
| ENGINE GENERATORS | | |
| Type | 8-Westinghouse revolving field alternators | 9 Westinghouse revolving field alternators |
| Capacity, rated, each | 5 000 kw. | 5 000 kw. |
| Overload, each | 50 per cent. | 50 per cent. |
| Cycles per second | 25 | 25 |
| Phases | 3 | 3 |
| Amperes, per phase, rated | 263 | 263 |
| Armature connected | Y | Y |
| Volts | 11 000 | 11 000 |
| Speed | 75 | 75 |
| Poles | 40 | 40 |
| Diameter revolving field | 32 ft. | 32 ft. |
| Circumferential speed | 7 540 ft. per min. | 7 540 ft. per min. |

| | 74TH STREET STATION | 59TH STREET STATION |
|---|---|---|
| ENGINE GENERATORS | | |
| Height, bed plates to top of frame | 41 ft. 11 in. | 41 ft. 11 in. |
| Segments in frame | 6 | 7 |
| Armature winding | 3 bars per slot; 12 slots per pole | 4 bars per slot; 9 slots per pole |
| Amperes in field | 202 | 202 |
| EXCITER GENERATORS | | |
| Number and drive | 4 Harrisburg tandem compound | 2 Westinghouse vertical cross-compound |
| Size | 14, 25 by 18 | 17, 27 by 24 |
| Capacity | 250 kw | 250 kw |
| Volts | 250 | 250 |
| Speed | 240 r. p. m. | 150 r. p. m. |
| Motor generators | | 3-250 kw |
| Storage battery | | 120 cells, R 51, chloride, capacity 3 000 ampere-hours at 1 hour rate |
| EXCITER CONDENSERS | | |
| Description | 2-motor, driven, triple single acting pumps, 18 in. by 12 in., Worthington jet | ........................ |
| HIGH TENSION SWITCHES | | |
| Type | G. E. Co., Type F-Form H. oil, motor operated | G. E. Co., Type F-Form H. 3; oil, motor operated |
| Arrangement | Each generator has one main and two selector oil switches to main bus | Each generator has one main and two selector oil switches to main bus |
| Feeder Switches | One to each feeder and two selector switches between each feeder group bus and main bus | One to each feeder and two selector switches between each feeder group bus and main bus |
| FEEDERS | | |
| Number and type | 35 No. 000 paper insulated lead sheath, three conductor cables<br>8 No. 0000 ditto | 39 No. 000 paper insulated lead sheath, three conductor cables<br>8 No. 0000 ditto<br>3 No. 6 ditto |
| GENERATOR RHEOSTATS | | |
| Type | Iron grid | Iron grid |
| Control | Motor | Motor |
| AUXILIARY POWER | | |
| Equipment | Three 800 kw 3 phase and 4 wire rotary converters with accompanying transformers and one bank of three 200 kw transformers | Exciters interchangeable for auxiliary power. Six 300 kw transformers in two banks |
| Volts | D. C. 500 and 250<br>A. C. 400 | D. C. 250<br>A. C. 400 |
| LIGHTING SYSTEM | | |
| Arrangement | Incandescent lamps; 4 in series on 500 volts, 2 in series on 250 volts<br>4 in series on 500 volts. Arc lamps in boiler room | D. C. 2 in series on 500 volts<br>A. C. single phase; 240 volt, 3 wire system. Nernst lamps 240 volts |

| | 74TH STREET STATION | 59TH STREET STATION |
|---|---|---|
| SWITCHBOARDS | | |
| Description | One board for generator and feeder instruments<br>One operating bench-board for generator and feeder oil switches*<br>One board for auxiliary power<br>One board for exciting current | One board for generator and feeder instruments<br>One operating bench-board for generator and feeder oil switches*<br>One board for auxiliary power<br>One board for exciting current<br>One operating bench-board for 60 cycle subway lighting (turbine) generators and feeders and board for instruments<br>One board for power station lighting |
| HIGH TENSION BUSSES | | |
| Main | 2 sets (duplicate)<br>8 groups (one for each selector switch) connected to each of the main bus sets through oil group switches | 2 sets (duplicate)<br>8 groups (each to contain one feeder to each selector switch) connected to each of the main bus sets through oil group switches |
| STORAGE BATTERIES | | |
| Number | 50 cells to operate motors of oil switches | 55 cells to operate motors of oil switches |
| Type | E. S. B. Co. 11-E. chloride | E. S. B. Co. 15-F chloride<br>(See *Exciters*) |

## SUB-STATIONS

| | MANHATTAN DIVISION | SUBWAY DIVISION |
|---|---|---|
| BUILDINGS | | |
| Dimensions | 50 ft. by 100 ft. | 50 ft. by 100 ft. |
| Number | 7 | 9 |
| ELEVATIONS | | |
| Basement to rotary (main floor) | 10 ft. 6 in. | 11 ft. 0 in. |
| Main floor to switchboard gallery | 17 ft. 6 in. | 15 ft. 0 in. |
| Main floor to crane rail | 28 ft. 6 in. | 25 ft. 0 in. |
| Cranes per station | 1—25-ton electric<br>2—10-ton hand | 2—25-ton hand |
| FEEDERS, D. C. | | |
| Description, length | 30-1 500 000 cir. mil. paper insulated, lead sheath, positive cables<br>65-1 500 000 cir. mil. weatherproof insulated cables<br>75-1 500 000 cir. mil. rubber insulated negative cables | 109-2 000 000 cir. mil. paper insulated, lead sheath, positive cables<br>106-2 000 000 cir. mil. paper insulated, lead sheath negative cables |

*Note:—Bench Boards are for oil switch control.

| | MANHATTAN DIVISION | SUBWAY DIVISION |
|---|---|---|
| HIGH TENSION SWITCHES | | |
| Type | G. E. Co., oil, type F-form H, motor operated | G. E. Co., oil, type F-form H 3, motor operated |
| Arrangement | 1 high-tension switch between bus and feeder; 1 high-tension switch between bus and rotary | 1 high-tension switch between bus and feeder; 1 high-tension switch between bus and rotary |
| SWITCHBOARDS | | |
| Description | Operating benchboard for control of oil switches. Marble board for D. C. switches and circuit breakers | Operating benchboard for control of oil switches. Bench-boards for circuit breaker control and switches for D. C. feeders and rotary converters. Circuit breakers in brick compartments |
| ROTARY CONVERTERS | | |
| Type and details | 41 Westinghouse Elec. & Mfg. Co., 1 500 kw. 3 phase, 25 cycle; 648 segments in commutator, 216 coils; 2 coils per slot, 6 bars per slot. | 43 Westinghouse Elec- & Mfg. Co., dropped frame, 1 500 kw., 3 phase, 25 cycle; 648 segments in commutator, 216 coils; 2 coils per slot, 6 bars per slot |
| Conv. height above floor. | 14 ft. 9 in. | 8 ft. 9 in. |
| D. C. voltage | 600 | 620 |
| TRANSFORMERS | | |
| Type and voltage | 550 kw., Westinghouse Elec. & Mfg. Co.; air blast, 10 500 to 405 volts | 550 kw., Westinghouse Elec. & Mfg. Co.; air blast, 10 500 to 411 volts |
| Location | On gallery, same height as switchboard gallery | On main floor |
| STARTING SETS | | |
| Description | 50 hp induction motor and D. C. generator | 100 hp induction motor and D. C. generator |
| BLOWERS FOR TRANSFORMERS | | |
| Size, source of power and number | 30 hp, 390 volt induction motor; 2 per station | 12 hp, 600 volt motors; 4 per station |
| Location | In basement | In basement |
| STORAGE BATTERIES | | |
| Size and use | 55 cells for operating oil smitches | 55 cells for operating oil switches |
| LIGHTING SYSTEM | | |
| Arrangement | 130 volt incandescent lamps on 125 volts A. C. | 130 volt incandescent lamps, 5 in series, on 600 volts D. C. |

## CABLE AND CONDUIT SYSTEMS

| | MANHATTAN DIVISION | SUBWAY DIVISION |
|---|---|---|
| CONDUIT | | |
| Total number of feet 3.5 in. vitrified duct....... | 1 463 044 ft. 1 in. | 6 650 166 ft. |
| Total number of feet of 3½ in. wrought iron pipe ................ | 22 296 ft. 0 in. | ........................ |
| CABLE APPROACHES | | |
| Location .............. | Two north and south of Harlem River, one at 128th St. and 2d Ave., one at 132d St. and Lincoln Ave. | Two north and south of Ship Canal, Kingsbridge, Broadway |
| MANHOLES | | |
| Total number ......... | 244 | 492 |
| Size .................... | 6 ft. wide, 8 ft. long and 6 ft. 6 in. deep | Tunnel manholes 12 ft. long, 5 ft. wide, 15 ft. deep. Street manholes 8 ft. long, 6 ft. wide, 7 ft. deep |
| A. C. CABLES | | |
| Description, length ..... | 43-3/0 3 conductor paper insulated, lead covered —728 308.44 ft.<br>4-4/0 3 conductor, ditto —51 577.75 ft. | 43-3/0 3 conductor paper insulated, lead covered —956 573 ft.<br>4-4/0 3 conductor, ditto —18 382.66 ft. |
| D. C. CABLES | | |
| Description, length ..... | 30-1 500 000 cir. mils paper insulated, lead covered — Positive 31 853 ft.<br>29-1 500 000 cir. mils rubber covered—Negative 32 910 ft. | 22-2 000 000 cir. mills paper insulated, lead covered—Positive and negative—509 106.80 |
| LIGHTING CABLE | | |
| Description, length ..... | 3-2 500 volt, 3 conductor No. 3 paper insulated, lead covered — 3 823.3 | 3-11 000 volt, 3 conductor, No. 6 paper insulated, lead covered—120 382 ft. |
| SUBMARINE CABLE | | |
| Description, length...... | 6-3/0 3 conductor rubber and lead, armored—3 606 ft.<br>4-1 500 000 cir. mils rubber and lead, armored 2 404 ft. | 2-No. 6 3 conductor rubber and lead, armored —1 000 ft.<br>4-3/0 3 conductor rubber and lead, armored—2 000 ft.<br>7-2 000 000 cir. mils rubber and lead, armored —3 500 ft. |
| MISCELLANEOUS CABLE | | |
| Length................. | 78 631 ft. | 111 682 ft. |

THE
# ELECTRIC JOURNAL

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**Synchronizing**

The article on "Synchronizing" by Messrs. MacGahan and Young, which appears in this issue of the JOURNAL, is interesting in that it illustrates the development of still another phase of the constantly recurring tendency in all lines of progress to substitute automatic machinery for operations which previously have been performed manually.

The process of synchronizing alternating-current machinery has never been considered one of extraordinary difficulty; still it is known that it is a process which requires knowledge, skill and training upon the part of the operator. Each time the operation is carried out the operator must use his skill and training in selecting the proper moment at which the synchronizing switch is to be closed. In other words, a mental effort is required for each operation of synchronizing. With the automatic machine this mental effort has been made once for all by the designer of the machine. For the knowledge, skill and training of the individual operator have been substituted once for all the knowledge, skill and training of a trained expert upon this matter. A single mental effort replaces the thousands of individual mental efforts which would otherwise be required.

The difference between machine operation and hand operation in a case of this kind is that the machine uses no judgment and makes no mistakes while the man may use judgment but is prone to make mistakes. The questions to be settled are (a) can personal judgment be dispensed with in synchronizing and (b) are manual mistakes more frequent than machine derangement? The experience already gained indicates that *yes* is the answer to both these questions. An affirmative answer to the first is of the greater importance, since the second depends only upon excellence of design—an element that is bound to advance, not recede, with time.

P. M. LINCOLN.

**Standard Voltages**

In the list of voltages recommended for alternating-current constant potential transmission circuits in the Standardization Rules of the American Institute of Electrical Engineers several common and familiar values are not found, for example, 13 200 volts and 50 000 volts are missing. The recommended list is 6 600, 11 000, 22 000, 33 000, 44 000, 66 000 and 88 000.

Such a simplification of general practice will be advantageous, for several more or less obvious reasons, both to the manufacturing and to the operating companies. Fewer classes of apparatus need be designed and constructed. Interchange of apparatus from one plant to another, either before shipment from the factory or in the field, will be facilitated. Plants which may be independently installed may, in the future, be combined into a single system with a facility, the lack of which has often caused much annoyance and expense in the past. If the recommendations made by the Institute in 1899 and in 1902 had been carefully adhered to, much difficulty and expense, both on the part of manufacturing and operating companies, would have been avoided.

One of the principal elements in the case is the transformer. It is recommended that standard transformer ratios should be a multiple of five or ten for transforming between high voltage transmission circuits and 2 200 volt distribution circuits. A general uniformity in transformer ratios, in the manner proposed, will be an important factor in practical standardization by eliminating much that is special, both in the factory and in the field. In cases where slightly different ratios are required, loops can be brought out from the windings, thus giving voltages in addition to that given by the normal ratio.

In the discussion concerning voltages before the Standardization Committee an interesting point was brought out showing the effect of the development of power transmission from a single transmission line to a general system. In the early transmission plants, where a single line ran from the generating station to a receiving station, the voltage at the latter could be held constant by suitable variation of the voltage at the power house. The normal voltage of the circuit might then be considered the delivered voltage and the apparatus at the power house should be suitable for an increase sufficient for overcoming the line drop. Later when several transmission circuits may run from a single power house and when there may be numerous sub-stations located at different points on the

same transmission circuit, it obviously becomes impossible to make adjustments at the power house which will deliver the desired voltage at each sub-station. It then becomes necessary to establish an average circuit voltage or to maintain a constant voltage at the power house and make adjustments at the sub-stations in order to secure the required pressure, unless the drop in the transmission circuits is so small as to be negligible. This difference in general practice has led to assigning standard values which are ten percent higher than those given in the earlier recommendations of the Institute, e. g., 6 600 and 11 000 instead of 6 000 and 10 000.

It is interesting to note that the highest voltage given in 1899 was 20 000 volts; in 1902, 60 000 volts; and in 1907, 88 000 volts. The only difference between the present list and the one which it supersedes is the omission of 15 000 volts, the addition of 88 000 volts and the change from voltage at the "receiving end" to "average voltage" with the consequent general increase of ten percent in the recommended values.

The recommendation for standard transmission voltages is one which should be carefully observed by engineers who are laying out new plants. It may seem a trivial matter to depart from the recommendations, when one has figured carefully that some intermediate voltage best meets his particular and special case. Due weight must be given, however, to the advantages of general conformity to a standard and this will usually overweigh the reasons in favor of special construction. It is only by individual concurrence with recommendations such as these that general uniformity can be secured.

CHAS. F. SCOTT

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**The Engineer and the Financier**

The announcement was recently made that a statue is to be erected in Trenton, N. J., to the memory of John A. Roebling, the engineer of the Brooklyn Bridge. Commenting on this announcement, the *Wall Street Journal,* in a recent editorial says, in part, as follows:—

"The tablet upon the bridge itself contains the names of all of the municipal officials who held office during the construction of the bridge, but it gives inadequate recognition to Roebling to whose genius alone the construction of the bridge is due.

"The engineer does the most important work in every great constructive undertaking. Next to him in importance comes the financier who has the courage and foresight to supply the capital which, joined with the skill of the engineer, makes the success of the enterprise possible.

"This is an age of engineering. Never has there been a time when the

engineer was so important to the world's progress as today. This is because this is an era of construction.

"Man works not for money alone but for recognition. We have no orders nor decorations nor titles in this country. By all means let us adopt every method possible to do honor to the men who do the great constructive work of the times."

The fact that the *Wall Street Journal*, a publication devoted exclusively to financial interests, considers that the engineer occupies a position more important than the financier's in his relation to constructive enterprises, and that his importance to the world's progress has never been so great as it is to-day, is good evidence that the world at large is beginning to concede to the engineering profession some of the honor and respect which in former years was rendered almost exclusively to other professions.

Young men about to choose a profession may do well to take note of this fact.

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**Clock=Face Diagrams**

It is seldom that an article, which presents such a formidable array of formulæ and trigonometrical quantities and subscripts as does the one on "Notation for Polyphase Circuits" in this issue of the JOURNAL, escapes the blue pencil of the editor. Moreover, he usually consigns such equations as are permitted to appear to foot-notes or an appendix.

In general the graphic method is most useful in studying and representing the phenomena which take place in electrical circuits as it has the advantage over algebraic representation in that it appeals to the eye and gives a good physical conception of the time relations as well as the values of the different quantities. Such diagrams are usually sufficient in themselves for the simpler cases. Care, however, must be exercised when the conditions become complex. Some method of systematic notation will then aid greatly in preventing errors in the interpretation of the diagram.

The method described by Mr. Porter will, I am sure, appeal to others as it has to me, as being both simple and rational. His application of the method to a few otherwise difficult problems shows the effective way in which it can be applied. The readers of the JOURNAL are to be congratulated on having so clearly presented such a ready and reliable method of solving many problems in connection with both single-phase and polyphase circuits, by means of the clock-face diagram.

CHAS. F. SCOTT

# SYNCHRONIZING

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## GENERAL

IN order to satisfactorily connect an alternating-current generator, rotary converter or synchronous motor to a system which is already in operation, it is necessary that certain conditions be complied with. The fundamental condition is that the electro-motive force of the incoming machine and of the system to which it is to be connected shall be approximately alike at each instant. This requires that the two frequencies shall be the same; that the two voltages shall be equal, as measured on a voltmeter; and that the two voltages shall be of the same phase, i. e., that their maximum and zero values are coincident. In other words, the speeds of the two machines must sustain a definite and exact relation, (the two speeds being equal if the number of poles of the generator and the incoming machine are the same); the field current must be adjusted to give the proper voltage, and the armature of the incoming machine must be in such a position with respect to its field poles that the electromotive force waves correspond in time with those of the generator.

Machines are said to be in synchronism when they agree in these particulars, and the operation of connecting the incoming machine to the system is termed "synchronizing." Synchronizing devices are employed for determining when the conditions proper for synchronizing are obtained.

## SYNCHRONIZING DEVICES

These are divided into two classes:

1. Visual or indicating devices.
2. Automatic devices.

*Requirements*—The ideal indicating synchronizer should perform three distinct functions:

1. It should indicate whether the incoming machine is running too slow or too fast.

2. It should indicate the amount by which an incoming machine is too slow or too fast.

3. It should indicate the exact time of coincidence in phase relation between the bus-bar and the incoming machine voltage waves.

*Use of Synchronizing Lamps*—Although lamps have been quite generally used for synchronizing, the method is not the best practice

for high voltages or large generators, nor wholly satisfactory for low voltage or small machines, as there is always the possibility of connecting a machine in parallel with others when a considerable difference in phase exists between the respective circuits. Furthermore, the operator has no means of judging phase difference except by interpolating in a succession of lamp brightnesses. The uncertainty of the lamp method makes the paralleling of machines a comparatively slow operation, as it is difficult to determine whether the speed of rotation of the incoming machine is too high or too low. An additional element of uncertainty is introduced by the fact that the lamps are affected by a difference in voltage as well as by the phase difference.

*Use of Synchroscopes*—By the use of a synchroscope it is possible to determine not only that there is a phase difference, but its amount; whether the incoming machine is too fast or too slow, and the exact moment when the machines are running synchronously and hence may be paralleled. Changes in voltage do not affect its action and the indications are accurate and easily read.

FIG. 1 -INDUCTOR TYPE SYNCHROSCOPE

*Operation of Synchroscope*—The synchroscope is so designed that the voltages of the incoming machine and bus-bars or line circuits act to rotate a pointer over a dial, the angle between the pointer and the vertical being always the phase angle between the two sources of electro-motive force to which the device is connected. If the incoming machine is running too fast, the pointer rotates in the direction, marked "Fast" upon the dial, and if the incoming machine is slow, the pointer moves in the direction marked "Slow" upon the dial. In either event, when the frequencies of the incoming and operating machines are the same and the phase relations are identical, the pointer remains stationary in a vertical position at zero.

There are two standard types of synchroscopes designed to meet different requirements of service, the "Inductor" type and the "Lincoln" type.

INDUCTOR TYPE SYNCHROSCOPE

This type is especially applicable where voltage transformers are already installed for use with other meters. As it requires only about ten apparent watts it may be used on the same transformers with other meters.

*Construction*—There are three stationary coils, *N, M* and *C* (Fig. 2), and a moving system comprising an iron armature, *A*, rigidly attached to a shaft, *S*, suitably pivoted and mounted in bearings, as shown in Fig. 1. A pointer, *B*, is also attached to the shaft *S*. The moving system is balanced and is not subjected to any re-

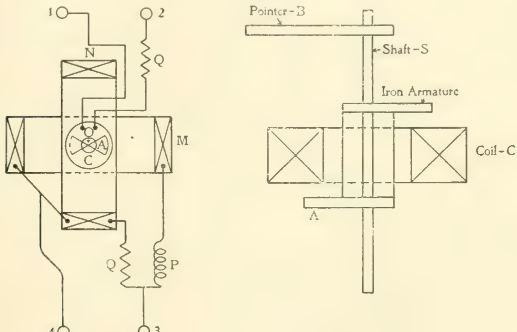


FIG. 2

straining force, such as a spring or gravity control. The coils *N* and *M* have their axes in the same vertical plane, but 90 degrees apart, while *C* has its axis in a horizontal plane. *N* and *M* are connected in "split phase" relation through an inductive resistance *P* and non-inductive resistance *Q*, and these two circuits are paralleled across the bus-bar terminals 3 and 4 of the synchroscope. Coil *C* is connected through a non-inductive resistance *Q* across the upper or machine terminals 1 and 2 of the synchroscope.

*Principle of Operation*—Current in the coil *C* magnetizes the iron core carried by the shaft and the two projections, marked *A* and *Iron Armature* in Fig 2. There is, however, no tendency to rotate the shaft. If current be passed through one of the other coils, say coil *M*, a magnetic field will be produced parallel with its axis. This will act on the projections of the iron armature, causing it to turn so that the positive and negative projections assume their appropriate position in the field of *M*. A reversal of the direction

of the current in both coils will obviously not affect the position of the armature; hence alternating current of the same frequency and phase in coils $C$ and $M$ cause the same directional effect upon the armature as if direct current were passed through the coils. If current lagging 90 degrees behind that in coil $M$ and coil $C$ be passed through coil $N$ it will cause no rotative effect upon the armature because the maximum value of the field which it produces will occur at the instant when the pole strength of the armature is zero. The two currents in coils $M$ and $N$ produce a shifting magnetic field which rotates about the shaft as an axis. As all currents are assumed to be of the same frequency, the rate of rotation of this field is such that its direction corresponds with that of the armature projections at the instants when the poles induced in them by the current in the coil $C$ are at maximum value and the field shifts through 180 degrees in the same interval as is required for reversal of the poles. This is the essential feature of the instrument, namely, that the armature projections take a position in the rotating magnetic field which corresponds to the direction of the field at the instant when the projections are magnetized to their maximum strength by current in coil $C$. If the frequency of the currents in the coils which produce the shifting field is less than that in the coil which magnetizes the armature, then the armature must turn in order that it may be parallel with the field when its poles are at maximum strength, consequently a rotation of its armature indicates a difference in frequency, and the rate and direction of rotation shows which current has the higher frequency and the amount of the difference.

### LINCOLN TYPE

This type has been developed for use in large stations where it is necessary that the instrument be visible from each prime mover or from a distance.

*Construction*—As may be seen by inspection of Fig 3, this instrument consists of an alternating-current bi-polar motor with a laminated iron field $M$ and core $D$ on which is wound a distributed two-phase winding $B$ and $C$ connected in "split phase" relation through a non-inductive resistance $O$ and an inductive resistance $P$. The resistance $O$ consists of the two stationary illuminating lamps, located behind the letters $F$ and $S$ on the glass dial, and the movable lamp attached to the indicating pointer. On $M$ are wound two field coils connected to the two right hand bus-bar leads 3 and 4.

Current is carried to and from the armature by means of a set of three collector rings and corresponding brushes. The armature shaft also carries an indicating pointer supporting the moving indicating lamp.

*Principle of Operation*—In a motor, such as is shown in Fig. 3, the armature tends to take such a position that the currents in its coils produce a magnetic field in the same direction as the magnetic field produced by the stationary field coils. If a direct current be passed through the field coils and also (in proper direction) through the armature coil *B* the armature will assume the position shown in the figure. If the direction be simultaneously reversed in both coils the position is obviously unaffected. Hence if alternating currents of the same frequency and phase be substituted for the direct current the position of the armature will remain unchanged. A second current having a difference of phase of 90 degrees may be passed through the coil *C* of the armature. This will not cause the position of the armature to shift for the reason that the magnetic field which it produces is a maximum when that produced by the stationary field coils is zero, hence there is no effective torque produced. The two currents in the armature produce a progressive shifting of the direction of the magnetic field and (as all currents are of the same frequency) the rate of rotation of this magnetic field is such that its direction coincides with that produced by the stationary field coils at the instant the latter is at maximum value. This is the essential feature of the instrument, namely, the rate of the physical rotation of the magnetic field produced in the armature must be such that it coincides in direction with the field produced by the stationary field coils when the latter is at its maximum value. As above described, if the frequency of the current in all the coils is the same, the armature stands at rest. Suppose that the frequency of the armature currents is less than that of the current in the sta-

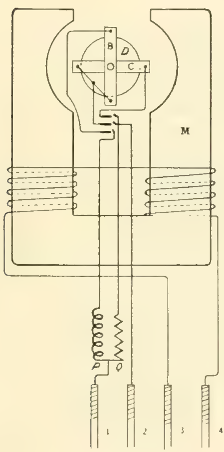

FIG. 3

tionary field coil. The rotating field does not shift quite 180 degrees while the stationary field reverses; hence a torque is produced and the armature turns. It tends to rotate at such a speed that its shifting field moves through a physical angle of 180 degrees during reversal of the field current; i. e., the speed of the armature rotation equals the deficiency in the magnetic rotation. The speed of the armature and the indicator carried by it, therefore, shows the difference in frequency between the alternating current in the armature and that in the field.

*Pointer and Dial Construction*—A tubular incandescent lamp is attached to the pointer, the dial having a dull black background. There are two incandescent lamps inside the case, serving to illuminate the letters *F* and *S*, indicating *Fast* and *Slow*. In addition to the openings in the dial in the form of the letters *F* and *S* there is between them a narrow opening lighted up by the internal lamps which marks the position that the pointer should have at the moment of synchronizing, as shown in Fig. 4.


FIG. 4—"LINCOLN" TYPE SYNCHROSCOPE
Dial 36 Inches in Diameter.

*Use of Lamps with Instruments*—It is advisable to use lamps as an additional check, as the synchroscope cannot follow the differential frequency when synchronizing is begun with a great difference in speed of the genereators. Synchronizing lamps should be used until the speed is correct within approximately ten percent, when the synchroscope will fall into step and indicate by the direction of its rotation the speed relation between the incoming machine and the bus-bars.

*Synchronizer in One-Phase*—A synchronizing device in one-phase is sufficient for paralleling machines after the correct permanent connections have been made to the synchronizing switches.

### AUTOMATIC SYNCHRONIZER

The automatic synchronizer is primarily intended for use in stations operating large capacity machines and where it is essential that synchronizing be done rapidly and safely.

*Requirements of the Automatic Synchronizer*—A successful automatic synchronizer should close the circuit when all of the conditions are suitable for closing, and it should prevent the closing of the circuit until these conditions are reached. This involves the following:—

1—It should permit the coupling of the machines as soon as the difference in speeds is within safe limits, and it should prevent the coupling of the machines at other times.

2—It should permit the coupling of the machines when the electro-motive forces are within proper limits, and should prevent the coupling when the electro-motive forces are too widely divergent.

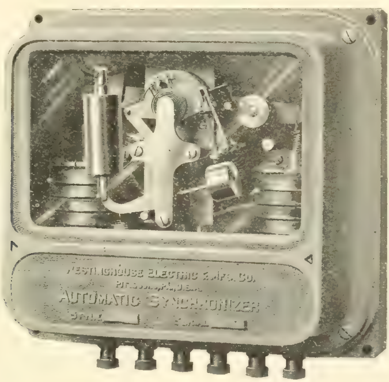


FIG. 5—AUTOMATIC SYNCHRONIZER

3—It should permit the coupling of the machines when the phase difference is within permissible limits, and should prevent the coupling when it exceeds these limits.

4—It should close the relay circuit for coupling the machines on the first occasion when the three foregoing conditions simultaneously occur.

5—It should close the relay contacts in advance of the period for coupling by a sufficient interval to allow the switch to act at the exact moment of synchronism. The greater the difference in speed the greater should be this advance in angle in order that the time allowed may be constant. As different types of switches require different amounts of time to close, the time of advance should be adjustable.

6—It should be certain and safe in its operation, and if anything in the mechanism fails it should prevent coupling.

*Use in Railway Power-House Plants*—The automatic synchronizer is especially well adapted for use in power stations of large railway systems. When accidents occur which entirely shut down one or more substations, it is exceedingly important to be able to start up with the least possible delay. With alternating-current starting motors and an automatic synchronizer for each rotary converter this can be done very quickly. Unless the voltage of the

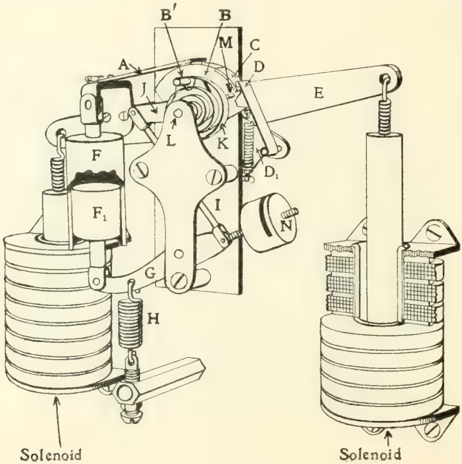


FIG. 6

system has been greatly disturbed it is simply necessary to close the starting motor switches and the automatic synchronizer will do the rest.

*Construction*—The working parts of an automatic synchronizer are shown in Fig. 6, in which:—

*A*—Sliding platinum-tipped contact attached to and actuated by the pivoted beam *E*.

*B*—Insulating segment secured to a sleeve loosely fitting pivoted shaft *L* and by means of pin *B'* actuated by pivoted levers *J* and *G*, the two latter being connected by a light connecting rod *I*.

*B'*—Pin secured to *B* and located between prongs of arm *J*.

*C*—Platinum-tipped contact secured to segment *B*.

*D*—Pivoted platinum-tipped contact controlled by spring *D'* and normally bearing on contact *C*.

*E*—Pivoted beam for suspending solenoid cores, actuating contact *A* and dash-pot shell *F* pivotally attached to *E*.

*F*—Shell of dash-pot pivotally attached to *E*.

*F'*—Piston of dash-pot attached to pivoted arm *G*.

*G*—Pivoted arm normally held in position by control spring *H*.

*H*—Control spring holding *F'-G-I-J* and *B* in normal position.

*I*—Connection rod transmitting motion of *F'* and *G* to *J*.

*J*—Two-pronged arm on shaft *L* and the right prong normally held by means of spring *K* against the small pin *B'* screwed into segment *B*.

*K*—Light controlling spring for *J*, the inner convolution being secured to *J* and the outer convolution secured to pin *B'*.

*L*—Pivoted shaft carrying segment *B* and forming bearing for *J*. This shaft is in same plane as bearing for *E*.

*M*—Pin on segment *B* and so arranged that it can engage projection on *D*, thus lifiing it from its normal position on contact *C*.

*N*—Adjustable control weight for varying movement speed of segment *B*.

The dash-pot shell *F* is provided at its top with a valve which opens on the downward stroke, thus allowing control spring *H* to instantly pull piston *F'* toward its initial position.

*Winding of Solenoids*—Each solenoid is wound in eight sections, alternate sections being connected in series, thus forming two circuits in each; one circuit of each solenoid being connected in series with a circuit of the other. This forms two independent circuits in the instrument, each circuit having half its turns on each solenoid as shown in Fig. 7.

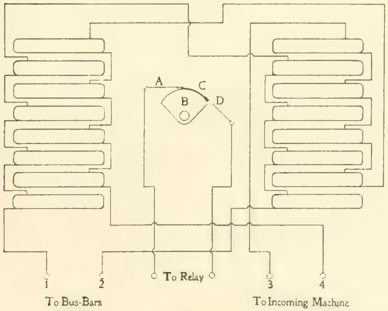


FIG. 7

*Action of Instruments*—With the incoming machine in phase with the running machine or in synchronism, the magnetic fields induced by the currents in the left hand solenoid oppose each other, thus neutralizing the pull on its iron core and at the same instant the magnetic fields induced by the currents in the right hand solenoid assist each other, thus giving a maximum pull on its iron core and drawing it to the bottom of the solenoid.

When the incoming machine is not in synchronism the magnetic fields induced by the currents in the left hand solenoid assist each other, thus exerting a maximum pull on its iron core, drawing it to the bottom of the solenoid. At the same instant the magnetic fields due to the currents in the right hand solenoid oppose each other, thus neutralizing the pull on its iron core. When the incoming and running machines are in 90-degree phase relation the solenoids exert equal pulls on their iron cores; which take up positions at equal distances from the bottom of each solenoid.

The displacement of the beam from the synchronizing position (due to differences in phase between machines) imparts to it a walking-beam action, and this movement up and down corresponds to the dark or light period of lamps or to the pointer rotation of the regular dial synchroscope.

1—That the incoming machine is almost in step and phase, i. e., synchronism with the running machine. It will be found that as it approaches synchronism, the right hand solenoid of the synchronizer will slowly pull its core down, thus raising the left end of beam $E$. The raising of $E$ will lift the dash-pot shell $F$ so slowly that the air escapes with sufficient freedom so that the piston $F'$ is not affected and is held at its normal position by the control spring H. With the position of the piston $F'$ undisturbed, the elements $G$, $I$, $J$ and $B$ will remain stationary so that the contact $C$ may for the moment be regarded as fixed in position.

The solenoid core will continue to travel slowly down until at exact synchronism it reaches the bottom of the solenoid and this movement will have caused contact $A$ to move forward and touch contact $C$, which already being in contact with $D$ will complete the relay circuit through the contacts $A$, $C$ and $D$ as shown in Fig. 6. The completion of this circuit will draw up the relay armature core, thus connecting in the solenoid that closes the main circuit breaker and connects in the generator.

2—That the difference in speed between incoming and running machines is somewhat greater than in the first case. It may be seen that the air in the dash-pot will not have sufficient time to escape and piston $F'$ will be drawn upward, thus advancing contact $C$ towards contact $A$. This movement will allow $C$ to make contact a little sooner than in the first case, thus energizing the relay and closing coil of the main switch a sufficient time ahead of

synchronism to allow the switch the necessary amount of time to overcome its lag element, thus closing just at or just before the time of exact synchronism, rather than just behind this point.

3—That the difference in speed between running and incoming machines is exceeded for safe synchronizing. The piston $F'$ will (by suction of $F$) be rapidly drawn far enough to advance $C$ a sufficient amount to enable the pin $M$ on segment $B$ to lift up contact $D$, thus opening the relay circuit and preventing closing of the main switch or breaker. It may be seen that the greater the speed difference between machines the greater advance $C$ will make toward $A$ owing to the fact that less air has time to escape from the dash-pot and the piston will, therefore, force $B$ further around. This condition will continue until the frequencies again approach within safe limits, when the action explained under the first and second cases will take place.

*Effect of Differences in Voltage*—If the voltage of the incoming machine differs considerably from that of the bus-bars to which it is to be connected the device will not close the contact since the effect of the excessive voltage on the left hand solenoid is to hold that end of the beam too low at the moment of synchronism. It is thus seen that the incoming machine will not be connected in parallel unless the voltages are approximately equal, the machine in phase with the line and the frequency correct.

*Use of Auxiliary Relay*—An auxiliary relay is used to avoid carrying the current of the main switch closing coil through the contacts of the automatic synchronizer. This relay consists of a simple solenoid having a core so located as to be drawn up and bridge two contacts in the circuit of the closing coil.

*Use of Control Switch*—A controlling switch, such as used with oil circuit breakers, is interposed in circuit with the synchronizer and electrically operated switch. By means of this control switch the main or electrically operated switch, or oil circuit breaker, may be tripped, but cannot be closed as the closing coil is normally out of circuit until the synchronizer completes the contact.

The control switch is of the drum construction, and when turned to the "trip" position the circuit through the trip coils of the main switch is completed, thus opening the connection from the machine to the bus-bars. At the same time current at approximately 100 volts from the alternating-current bus-bars is connected to the

left hand pair of binding posts of the synchronizer, which brings the rocker arm from the synchronous position to the horizontal position, thus opening the synchronizer contacts and leaving them in a safe position.

On turning the control switch to the closed position approximately 100 volts alternating current from both the bus-bars and the incoming machine is connected to the synchronizer and the rocker arm begins to oscillate rapidly. Immediately the closing circuit is completed as far as the axuiliary relay and the direct current which operates the relay is closed as far as the synchronizer. When the synchronizer closes its contacts the relay also closes and operates the main switch. On returning to "off" position after closing the main switch the controller opens the direct-current circuits to the synchronizer and to the closing coil of the main switch, this latter circuit being opened in a second place by the relay. An instant later the transformers are disconnected from the synchronizer.

# NOTATION FOR POLYPHASE CIRCUITS

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IN the working out of the current and voltage relations in the simplest polyphase circuits the particular notation employed is not important. In the more complex cases, however, any lack of definiteness in the notation or its interpretation is almost sure to result in confusion, at least in the case of students. The following notation is so obvious that it must be more or less generally used, but so far as the writer knows no description of it has been published.

This notation is based essentially on lettering *every* junction and terminal on the diagram of connections and on the use of *two* subscripts with *every* symbol of current or electro-motive force or vector representing them. The vector diagram must be carefully distinguished from the diagram of connections although there is a certain similarity between them in the simpler cases. The subscripts, taken from the diagram of connections, indicate that the positive direction of the current is from the first to the second and that the positive direction of the electro-motive force is such that the first point is of higher potential than the second. The current $I_{AB}$ then is the current, the positive direction of which is from A to B in the branch AB and $E_{AB}$ is the electro-motive force which produces this current. Equally $I_{BA}$ is the current the positive direction of which is from B to A and it is produced by the electro-motive force $E_{BA}$. Again, $I_{AB}$ is equal to $-I_{BA}$, and $I_{AB}$ and $I_{BA}$ differ in phase by 180 degrees. It must therefore be obvious that the order of the subscripts is a matter of vital importance. If the circuit between A and B consists of pure resistance only, $E_{AB}$ and $I_{AB}$ will be in phase. For any branch not containing a source of electro-motive force the equation, $I_{AB}=\frac{E_{AB}}{Z}$ is of course true, where $E_{AB}$ is the voltage across the impedance between the points A and B, and Z, equal to $\sqrt{r^2+x^2}$, is this impedance, r its resistance and x its reactance. The tangent of the phase angle, $\Theta$ or angle of lag or lead of the current, $I_{AB}$, with respect to the electro-motive force, $E_{AB}$, is the angle whose tangent is the ratio of the reactance to the resistance or $\frac{x}{r}$. In general there is more interest in knowing the power

and power-factor of a circuit than its constants, and the phase relation between $I_{AB}$ and $E_{AB}$ will more commonly be determined from the fact that the power-factor or ratio of true watts to volt-amperes is equal to the cosine of the phase angle.

When, in specific problems, exact numerical results are required an analytical solution by the method of complex quantities is much to be preferred to a purely graphical one. Experience with students at the Massachusetts Institute of Technology, however, has shown conclusively that, even though a problem is to be solved analytically, an approximate vector diagram should always be drawn as it facilitates the interpretation of the work and serves as a check against slips, and also that the drawing of all vectors on any polyphase vector diagram *radially* from a common center is second in importance only to the use of two subscripts. When the vectors are so drawn there can be no question as to the phase relation between any two vectors on the diagram and if each vector be lettered with two subscripts there is no excuse for mistaking the angle between $E_{AB}$ and $I_{CD}$ for the angle between $E_{AB}$ and $I_{DC}$ the latter angle being the supplement of the former. If in the case of three-phase circuits some of the vectors are drawn from each vertex of a triangle, as is sometimes done, and especially if only one subscript be used as $E_1$ or $I_2$ the student is liable to add some vector which should be subtracted or subtract one which should be added.

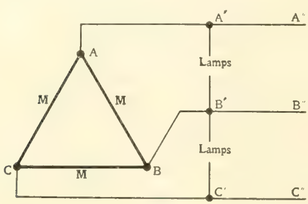

FIG. 1

From a theoretical standpoint a further advantage of the radial vector diagram is that if it be scaled to represent maximum values instead of effective values, the instantaneous value and direction of any current or electro-motive force at any instant of time will be given by the projection of the corresponding vector on the perpendicular to the positive direction of the time axis at that instant. If lag be regarded as positive or lead as negative when measured in a clockwise direction, the time axis can be considered as fixed and the vectors to rotate in a counter-clockwise direction, or the vectors can be considered as fixed and the time axis to rotate in a clockwise direction, one complete revolution corresponding to a complete cycle.

PROBLEM I

The method of using these principles can perhaps be brought

out more fully by applying them to specific problems. As a first example there will be given a determination of the magnitudes and phase relations of the currents in the branch circuits and mains of a 400-volt, three-phase system with an induction motor load of 100 kw at 80 percent power-factor and in addition incandescent lamp loads of 40 kw at 100 percent power-factor on two of the phases.

The diagram of connections is shown in Fig. 1 and the three-phase voltage will, in accordance with the notation, be either $E_{AB}$ $E_{BC}$ and $E_{CA}$ or $E_{AC}$, $E_{CB}$ and $E_{BA}$ It will be assumed that the e.m.f.'s across all three phases are equal and that they can therefore be vectorially represented by three equal radiating lines differing in phase by 120 degrees. In this and the following three-phase problems it is always assumed that the sequence of phases is $A—B—C$ not $A—C—B$, or that when the voltages are symmetrical

$$\text{if } E_{AB} = E \sin(pt + \Theta)$$
$$\text{then } E_{BC} = E \sin(pt + \Theta - 120^\circ)$$
$$\text{and } E_{CA} = E \sin(pt + \Theta - 240^\circ)$$

Lead is also always regarded as positive when laid off in a counter-clockwise direction on the vector diagram, or lag as positive when measured in a clockwise direction.

A strict adherence to these conventions in each and every problem attacked will entirely eliminate the possibility of a certain class of "slips." The electro-motive force vectors are shown as heavy lines in Fig. 2 and are lettered in accordance with the conventions.

Next the currents in the branch circuits must be determined. The induction motor is taking 100 kw at 80 percent power-factor or $100 \div 0.8 = 125$ kilovolt-amperes. The k.v.a. per phase are then, $125 \div 3 = 41.7$ and since the delta voltage is 400 volts the delta current will be $41\,700 \div 400$ or 104 amperes per phase. As the power-factor is 80 percent the cosine of the lag angle is 0.8, which corresponds to an angle of approximately 37 degrees. The currents $I_{AB}$ $I_{BC}$ and $I_{CA}$ can therefore be drawn to scale, each one lagging 37 degrees in a clockwise direction, with respect to the corresponding electro-motive forces $E_{AB}$, $E_{BC}$ and $E_{CA}$. If instead of induction motors the load consisted of over-excited synchronous motors at the same power-factor the delta currents would *lead* the delta electro-motive forces instead of lagging with respect to them.

Assuming that the resistance of the connections between $A'$ and and $A$, $B'$ and $B$ and $C'$ and $C$ is negligible the voltages $E_{A'B'}$ and $E_{B'C'}$ will be the same as the voltages $E_{AB}$ and $E_{BC}$. The current taken by the lamp load of 40 kw at 100 percent power-factor and

400 volts will be 40 000 : 400, or $I_{A'B'}$ is 100 amperes and since the power-factor is unity $E_{AB}$ and $I_{A'B'}$ are in phase and the vectors representing them, in Fig. 2, must coincide in direction. Similarly $I_{B'C'} = 100$ amperes and is in phase with $E_{BC}$.

The currents in the several branches having been determined the currents in the mains can readily be found by *vector* addition. Vector equations, analagous to the algebraic equations for steady currents and electro-motive forces, can of course, be written for

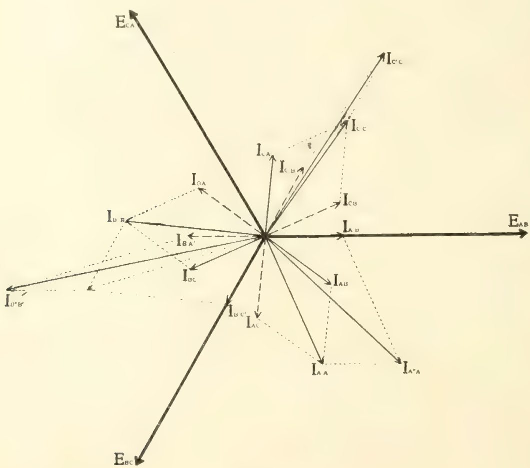


FIG. 2

polyphase circuits. The fact that all of the equations used in these problems are *vector* equations cannot be too strongly emphasized. The current in one main due to the induction motor load is

$$I_{A'A} = I_{AB} + I_{AC} = I_{AB} - I_{CA}$$

and is obviously $\sqrt{3}$ times the delta current or $104\ \sqrt{3} = 180$ amperes. The currents $I_{B'B}$ and $I_{C'C}$ must be equal to $I_{A'A}$ in magnitude and 120 degrees from it in phase. The total current in main $A$ is $I_{A''A'} = I_{A'A} + I_{A'B'}$ and its magnitude as scaled from the vector diagram is 240 amperes.

Similarly, $-I_{B''B'} = I_{B'B'} + I_{B'A} + I_{B'C'} = I_{B'B} - I_{A'B'} + I_{B'C'}$

The corresponding vectors are combined on the diagram in accordance with these equations and the resultant current $I_{B''B'}$ is 340 amperes. The current in the third main is,—

$$I_{C''C} = I_{C'C} \quad I_{C'B'} = I_{C'C} - I_{B'C'}$$

and its value is 280 amperes.

As the notation is fully shown by the above equations and by the vector diagram the computation of the values by analytical methods will be omitted. It may be well to emphasize at this point that any such convention as that "currents from right to left or flowing outward or flowing in a clockwise direction in a mesh are considered as positive" is not only unnecessary but positively undesirable as it makes the notation less broad and flexible and is more or less equivalent to restricting the use of any pair of subscripts to one order and only one.

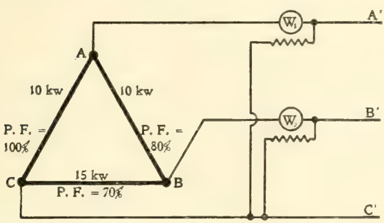


FIG. 3

PROBLEM II

Some additional points can be brought out by considering the case of a three-phase delta system with badly unbalanced loads and voltages and the measurement of the total power therein by the two wattmeter method. Calling the mains $A$, $B$ and $C$ let the voltages between $A$ and $B$, $B$ and $C$ and $C$ and $A$ be respectively 220 volts, 200 volts, and 240 volts, and let the load between $A$ and $B$ be ten kw at 80 percent power-factor; between $B$ and $C$, 15 kw at 70 percent power-factor and between $C$ and $A$ a non-inductive load of ten kw. These are indicated on the diagram of conections, Fig. 3.

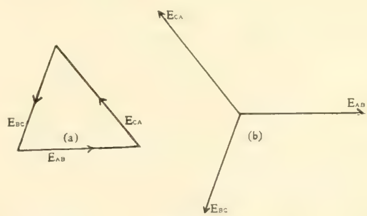


FIG. 4

The phase relations of the three voltages can be best determined graphically by constructing a triangle, as in Fig. 4 (a), the

sides of which are proportional to the given voltages and then transforming this into a radial vector diagram by drawing vectors parallel to the sides of the triangle as in Fig. 4 (b).

The current $I_{AB}$ can be found by dividing the volt-amperes or $10\,000 \div 0.8 = 12\,500$ by the voltage $E_{AB}=220$ volts. Hence $I_{AB}=57$ amperes and it lags with respect to $E_{AB}$ by 37 degrees. Similarly $I_{BC}=107$ amperes and lags with respect to $E_{BC}$ by the angle whose cosine is 0.7 or 45.5 degrees and $I_{CA}=42$ amperes and is in phase with $E_{CA}$.

The currents in the mains (See Fig. 3) are,—

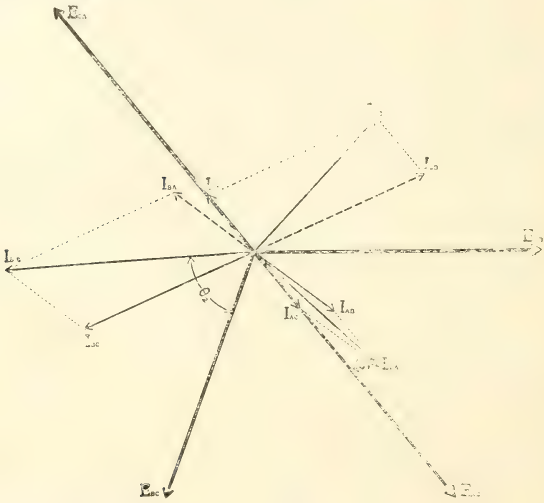

FIG. 5

$$I_{A'A} = I_{AB} + I_{AC} = I_{AB} - I_{CA}$$

$$I_{B'B} = I_{BC} + I_{BA} = I_{BC} - I_{AB}$$

$$I_{C'C} = I_{CA} + I_{CB} = I_{CA} - I_{BC}$$

and from Fig. 5 their numerical values are found to be,—

$I_{A'A} = 98$ amperes, $I_{B'B} = 144$ amperes and $I_{C'C} = 104$ amperes.

If the total power in this system is to be measured by the usual two wattmeter method and the wattmeters are connected with their current coils in mains $A$ and $B$ and their potential coils between mains $A$ and $C$ and $B$ and $C$ as shown in Fig 3

Then $W_1 = E_{AC} \times I_{A'A} \times \cos \Theta_1$ where $\Theta_1$ is the angle between $E_{AC}$ and $I_{A'A}$ (not that between $E_{CA}$ and $I_{A'A}$) and $W_2 = E_{BC} \times I_{B'B} \times \cos \Theta_2$ where $\Theta_2$ is the angle between $E_{BC}$ and $I_{B'B}$. From the vector diagram it will be found that $\Theta_1 = 8.4$ degrees and $\Theta_2 = 66$ degrees

$$\text{Therefore } W_1 = 240 \times 98 \cos 8.4^\circ = 23.2 \text{ kw}$$
$$\text{and } W_2 = 100 \times 144 \cos 66^\circ = 11.8 \text{ kw.}$$

The total power $W_0 = W_1 + W_2 = 35$ kw which checks with the total power in the original statement of the problem which was $10+15+10=35$ kw. If either $\Theta_1$ or $\Theta_2$ had been greater than 90 degrees the reading of the corresponding wattmeter would be regarded as negative and the true power would have been the numerical difference between $W_1$ and $W_2$.

PROBLEM III

As a further example of the method the currents in the mains and in the neutral of a three-phase, 220-volt, Y system loaded with five known impedances as indicated in the diagram of connections, Fig. 6, may be determined, assuming that both the delta and also the Y voltages are equal and therefore differ in phase by 120 degrees and that the values of the impedances are,—

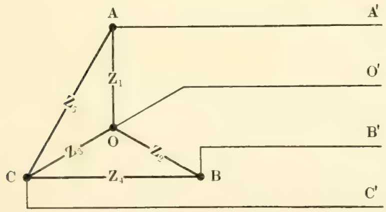


FIG. 6

$$Z_1 = 25 + j\ 0,\quad Z_2 = 15 + j\ 20$$
$$Z_3 = 20 - j\ 15,\quad Z_4 = 25 + j\ 25$$
$$Z_5 = 25 + j\ 10;$$

Then the Y voltages $E_{OA}$, $E_{OB}$ and $E_{CO}$ are each equal to $220 \div 3$ or 127 volts and they can therefore be drawn to scale as in Fig. 7, The delta voltages can be found from the vector equations

$$E_{AB} = E_{AO} + E_{OB} = E_{AO} - E_{BO}$$
$$E_{BC} = E_{BO} + E_{OC} = E_{BO} - E_{CO}$$
$$E_{CA} = E_{CO} + E_{OA} = E_{CO} - E_{AO}$$

Obviously the start could have been made equally well with the Y voltages $E_{OA}$, $E_{OB}$ and $E_{OC}$.

The current $I$ in each impedance is obtained by dividing each value of $E$ by the corresponding ohmic value of $Z$ which is equal to $\sqrt{r^2+x^2}$ and the tangent of the phase angle between $E$ and $I$ is given by $\tan\theta = \frac{x}{r}$

$I_{AO} = \frac{127}{25} = 5.1$ amperes and is in phase with $E_{AO}$

$I_{BO} = \frac{127}{\sqrt{225+400}} = 5.1$ amperes and lags behind $E_{BO}$ by the angle whose tangent is $\frac{20}{15}$ or an angle of 53 degrees.

$I_{CO} = \frac{127}{\sqrt{400+225}} = 5.1$ amperes but *leads* $E_{CO}$ by the angle whose tangent is $\frac{15}{20}$ or an angle of 37 degrees.

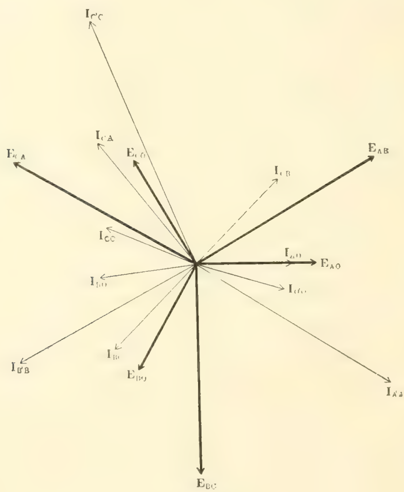


FIG. 7

$I_{BC} = \frac{220}{\sqrt{625+625}} = 6.2$ amperes and lags behind $E_{BC}$ by an angle of 45 degrees.

$I_{CA} = \frac{220}{\sqrt{625+100}} = 8.2$ amperes and lags behind $E_{CA}$ by an angle of 22 degrees.

All of these currents are therefore completely determined and the corresponding victors can be drawn to scale as in Fig. 7.

The currents in the mains are found from the vector equation,—

$$I_{A'A} = I_{AO} + I_{AC} \qquad I_{AO} - I_{CA} \text{ or } I_{A'A} = -I_{OA} - I_{CA}$$
$$I_{B'B} = I_{BO} \qquad I_{BC}$$
$$I_{C'C} = I_{CO} + I_{CA} \qquad I_{CB} = I_{CO} \qquad I_{CA} - I_{BC}$$

The current in the neutral is equal to the vector sum of the Y currents and must also equal the vector sum of the currents in the mains. Hence,—

$$I_{O'O} = I_{OA} + I_{OB} + I_{OC} \text{ or}$$
$$I_{OO'} = I_{AO} + I_{BO} + I_{CO}$$
$$= I_{A'A} + I_{B'B} + I_{C'C}$$

The resultant current in each case is shown on the vector diagram and the values are

$$I_{A'A} = 12.2 \text{ amperes}$$
$$I_{B'B} = 10.8 \quad \text{“}$$
$$I_{C'C} = 14.2 \quad \text{“}$$
$$I_{O'O} = 4.8 \quad \text{“}$$

It will be noticed that if $Z_2$ and $Z_3$ be interchanged $I_{O'O}$ the current in the neutral will no longer be 4.8 amperes but will be 7.8 amperes and its phase with regard to the impressed e.m.f.'s will be shifted by almost 180 degrees. The currents in the mains will also be changed in both magnitude and phase.

In the case of three-wire or four-wire interlinked two-phase systems the currents can be determined in exactly the same manner as in the previous three-phase problems the only difference being that the fundamental electro-motive forces are assumed to be 90 degrees apart instead of 120 degrees.

# REMOVAL OF LIMITATIONS BY ELECTRICITY*

CHAS. F. SCOTT

EVERY engineering problem involves certain fixed and definite limitations. The methods and the results are subject to these limitations. Sometimes the limits are fixed by the strength or other physical properties of the available materials; sometimes by the forces or the power which are available, and sometimes by surrounding conditions of various kinds. If a mathematical equation contains constants, they, in a large measure, determine the form of the corresponding curve. Change the constants and the whole aspect of the curve is changed. Likewise in engineering work, if the constants which have been the determining elements are modified new possibilities are created. The discovery of a new element or a new property of matter or of a new method of operation opens new fields of activity. The application of electricity leads to new methods, because it removes many of the limitations which previously existed. Summarized in a word, therefore, the secret of electrical development is this: Electricity removes former limitations.

The manufacture or generation of power is a fundamental element underlying modern progress. How does electricity remove the limitations which formerly existed in producing power?

In order that an engine may be mechanically connected to its load it must run at a speed suitable for connection to the machinery to be driven and it must be located within a short distance from it. The limited range in distance and the mechanical difficulties in sub-dividing and distributing power, therefore, require that the various machines to be operated be clustered closely about the engine. That is, the engine must be brought to the work, or the work must be brought to the engine. If the machines to be operated are widely scattered, separate engines are necessary. These limitations are removed when electrical methods of distribution are employed. Power can be supplied from a central plant and distributed over a distance of many miles. Hence, the size of the engines in which the power is to be generated is not fixed by the work which lies within a limited radius of a few hundred feet.

Generally speaking, the prime mover in the electric power station may now be made of any output at any speed. Consequently,

*Extracts from an address delivered at Worcester Polytechnic Institute, June 13, 1907.

the size and speed of power units have increased until values have been reached which can find no practical application except the driving of electric generators. This reflex effect of the electric system upon the development of engines is significant. The sudden advent of the steam turbine has resulted in practically its complete substitution for the large reciprocating steam engine after its growth of a century and its recent construction in large sizes for electric driving. In addition to its economies in operation the smaller space requirements of the steam turbine and its general characteristics enable improvements to be made in power-house construction and arrangement.

There is another change coming about in power generation. The gas engine of large sizes is now coming into use for the driving of electric generators. It is notable that the new Indiana plant of the United States Steel Corporation, which will present not only the most modern but one of the largest industrial plants in existence, is discarding entirely the steam engine and will depend upon the electric power derived from gas-engine-driven generators. This will place upon electric motors more severe service than has ever been exacted. Motors must now be built not only in sizes larger than have ever been used, but motors driving the rolls which require thousands of horse-power must be reversed in a few seconds. By this means what have been waste gases from the blast furnaces now become the sole source of power. The gas engine does not have overload capacity and cannot be used where reversal of speed is required. Hence, it is the electric system which makes possible the use of the gas engine in this plant.

The electrical system, therefore, by removing the mechanical difficulties and limitations in the distribution of power has completely revolutionized the methods of generating power, making possible the concentration of the generation of power for large areas in a single power plant, in which new types of apparatus are employed which would otherwise be useless. The electric transmission of power has not only led to a complete readjustment of the methods of power generation from fuel but it has brought into service water power.

In the generation of power electricity allows the prime mover to be remote from the work to be done, it permits the production of power in enormous quantity, as it may be sub-divided for a thousand or a million uses, and it enables the power plant to be designed and located solely with a view to the efficient production of power. The net result is cheap power.

When we pass from the generation of power to its application, we find even more striking illustrations of the new methods which are possible when the former limitations are removed by the adoption of improved methods.

We are first of all struck with the variety of uses to which electricity may be applied. This follows primarily from the facility with which electric energy may be transformed into mechanical energy, or heat or light, or chemical energy. While there is a fundamental relation between energy in its various forms, there is no other medium of conversion from one form to another which is in any way practically comparable with electricity. Hence the old limitations in the use of power are removed and new fields of application are opened.

The substitution of the steam locomotive for animal power in transportation has been one of the principal factors which underlies our present civilization.

Speed and power in ordinary transportation were still limited by the capabilities of the horse. The electric motor made available a source of practically unlimited power, which could be developed on the car in any desired amount, at a speed the limits of which were not fixed by the motive power but by the conditions of expediency or safety, and with a capacity for continuous operation.

The steam locomotive has two limitations; it cannot economically be made for small powers, and, on the other hand, it has its limitations in the other direction, for, like the horse-car, it is limited in the power and in the speed which it can develop and in its endurance.

The steam locomotive is a power house on wheels. Its supply of fuel and of water, its furnace, its boiler and the engine must all be combined in one compact unit. The width is limited by the gauge of the track. The height is limited by the dimensions of bridges and tunnels. The length of the driving parts is limited by the permissible length of the rigid wheel base. The tractive effort is limited by the weight on the drivers. The weight is limited by the quality of the road bed and rails. The speed is limited on account of the reciprocating parts. Both speed and endurance are limited by steaming capacity. These various limitations, with their various mutual inter-relations, are among the factors which have brought the steam locomotive in its latest types to approximately its practical limits.

The principal substitutions of the steam locomotive by electricity have been radical ones, for not only the steam but even the locomotives themselves have been eliminated.

In the multiple-unit operation of elevated and subway trains, the power is applied directly to the axles of the cars. All motors are under the control of a single motorman. This simple method is quite out of the question in steam operation, and it overcomes another limit of the steam locomotive,—namely, its tractive effort. This is determined by the weight upon the drivers. In the multiple unit system, however, the active weight of the train is made available for increasing the tractive effort. It would require several large steam locomotives to accelerate the trains in the New York Subway as rapidly as they are now accelerated in their daily service.

The electric locomotive conveniently overcomes the limitations of the steam locomotive. Its power plant is not portable, but is a great central station with indefinite output. The driving axles need not be rigidly connected by side rods, but may be grouped on independent trucks, thus lending themselves to a ready flexibility. Several individual locomotive units may be joined together and operated by a single motorman by means of the multiple-unit control system. Thus, the driving action may be derived from many drivers and the tractive effort is not limited by the permissible weight upon two or three pairs of drivers, as is the case with the steam locomotive. The speed is not limited by reciprocating parts, and all weight, except that of the wheels and axles, may be spring supported. Consequently, the limitations as to tractive effort, as to maximum speed and as to horsepower, which are inherent in the steam locomotive, do not obtain with the electric locomotive. Hence the practical limits with respect to these elements do not lie in the locomotive but in the other parts of the system. An examination of the development of railways shows that many of the present methods of operation have been determined by the characteristics of the locomotive. The changes which will follow electric operation may be of far greater consequence than the mere substitution of one locomotive for another. It may go much further and have a marked influence upon the methods of railway operation. Here, again, it is the removal of old limitations which assures the supremacy of the smokeless electric locomotive.

Since the days of James Watt there have been two lines of development which underlie our industrial progress. One of these has been the steam engine, by which power is produced; the other has been the tool, which the power drives. Means of transmitting the power from the engine to the tool did not keep pace either with the development of engine or of machinery. Hence, the introduction of

the electric system of distributing and applying power found a waiting field. It is interesting to note the careful comparisons between the efficiency of mechanical and of electrical methods of transmission which were presented a number of years ago in connection with the electric drive. The introduction of electric motors, however, did not make much headway so long as mere efficiency in the transmission of power was the principal reason urged. True, there is power economy in the electric system, but the great gain in the use of motors is through the general adaptability and convenience which results and in the increased output which can be produced. The location of buildings, the placing of machinery, the selection of individual or group drive, are all dependent upon general considerations and are no longer controlled by the limits prescribed by shafting. The gain in headroom through the absence of shafting and belts, the readiness to start, the reduced fire risk, and the convenience in distant control of the motors,—all indicate the new methods which the electric motor brings. In the operation of machinery, the facility for supplying any amount of power at any speed and the ability to vary and adjust the speed or to maintain a constant speed are often essential for securing increase in the quantity and the quality of any product. In certain spinning mills the motor insures a constancy of speed, which permits a higher speed to be employed than was practicable with belt drive from engines; this results in an increase of output of improved quality, which alone justifies the installation of the electric plant. The new high-speed tool steels call for increased power at closely controlled speeds, which are practically impossible without motor drive. Whether the requirement be for constancy of speed for delicate work, or for speed adjustment, or for the operation of enormous reversing rolls in steel mills, it is the electric motor which best meets the requirements.

If we were to investigate the results which have followed the introduction of power in mining and in other fields, such as illumination, electro-chemistry, the telegraph, the cable and the telephone, we would find similar improvements and modified methods, resulting from the applications of electricity. Possibly in no single instance has there been a greater change in everyday business and social life than that brought about by the telephone. Here again, it is a removal of limitations. The range of the human voice has been extended from a few yards to thousands of miles. The telephone is the high-speed tool of general life.

We have seen how the operations and methods of every art

where power is applied are limited and determined by the inherent qualities of the apparatus. We have seen how these limitations have been changed or removed by the introduction of electricity. Hence, there is no other branch of engineering in which there is such a field for the constructive enginering imagination. In making the application of the electric motor to an old industry, for example, it is not unusual for the electrical engineer from his independent point of view to observe the difficulties which have existed and suggest new methods of operation by which they may be overcome. The electrical engineer must be capable of new things. If a young man had been made acquainted with the construction and operation of all kinds of commercial apparatus ten years ago and had relied upon this practical knowledge of apparatus as the basis of his electrical training, he would have found it of only temporary value. Only a small proportion of the electrical apparatus produced to-day is identical with that made even four or five years ago. Styles and types have changed and new kinds of apparatus are being produced; new methods are employed. The electrical engineer, therefore, must be capable of new things.

Electricity is a co-operative influence. It calls for harmony in the different branches of engineering, and in pure science it gives promise of furnishing the key to the mysteries which are back of our present knowledge of the theories of matter and force. It lays the foundation for industrial and commercial operations on a large scale.

Our whole life is a struggle against surrounding limitations. The triumph of our modern life, with its magnitude of achievements, is the result of concerted action. Unity of interest and co-operation in action give the stimulus and the means for progress. This wider field of action in industry, in state and nation and in the world at large requires interchange of ideas, of commodities and of men. Limitations as to space and time and power hold men in check. When once these are enlarged, new possibilities and new opportunities come, and a marvelous development follows. Herein has been the achievement of the engineer. When he extended the radius of easy travel and cheap transportation and instantanous communication, civilization took on a new aspect.

# RAILWAY SIGNALING—VII

## AUTOMATIC BLOCK SIGNALING—ALTERNATING-CURRENT

J. B. STRUBLE

### GENERAL

THE proper operation of a direct-current track circuit may be interfered with when the track rails have the additional duty of conducting current for other purposes, such as the propulsion of trains. It has, therefore, become necessary to use a kind of signaling current in the rails which, while performing the functions previously described, will in addition be able to operate a track relay selectively; i. e., which will respond to the signaling current

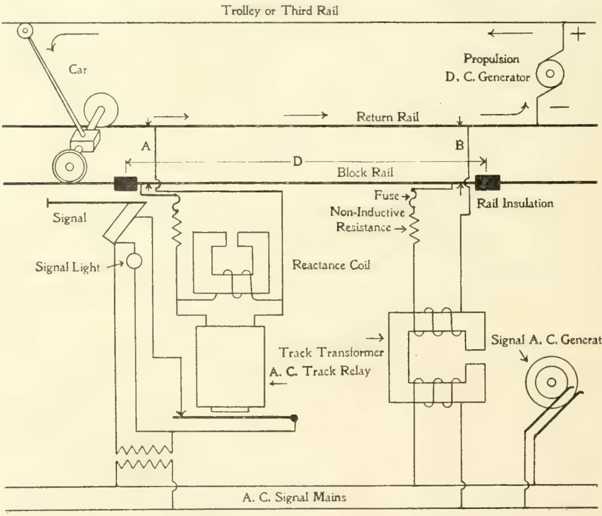


FIG. 1—TYPICAL ALTERNATING-CURRENT TRACK CIRCUIT USING THE SINGLE-RAIL SCHEME

and to no other. Thus alternating current, because of its inductive properties, has been substituted for direct current.

Two schemes of alternating current are in use, the single-rail return system and the double-rail return system. In the former, one rail of each track is insulated into block sections for signaling

purposes, the other rail serving as a continuous return for the power current and as one side of the alternating-current track circuit. In the latter, both are insulated into block sections and both are used for the power current. This is accomplished by the use of balanced inductive bonds and is used in preference to the single-rail system under certain conditions. The single-rail scheme and some features of interest in its application will be considered in this article.

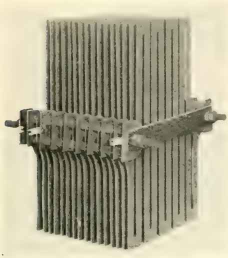

FIG. 2—FORM OF GRID USED FOR NON-INDUCTIVE RESISTANCE

SINGLE-RAIL SYSTEM

Fig. 1 shows a typical alternating-current track circuit using the single-rail scheme, and its relation to the propulsion system. As practically all of the propulsion current flows through the return rail within the distance, *D*, the length of the block, and relatively little through the block rail, there will be a drop in voltage in the former and not in the latter. This drop appears at *A* and at *B*, the sum of which will equal *D*. Thus a small amount of propulsion current will flow through a track relay at one end of the section and through the secondary of the track transformer at the other, the effect of which is to magnetize the iron of each to a certain extent and, if excessive, to diminish the influence of the alternating signal current. In order to limit this effect of the propulsion current on the relay, a non-inductive resistance, Fig. 2, is connected in series with the relay and a reactance, Fig. 3, of low ohmic resistance in multiple with the relay. In like manner the track transformer, Fig. 4, is protected by a non-inductive resistance in series with it. As a further precaution against the magnetizing effect of the propulsion current, the iron of both transformer and reactance coil is provided with an air gap. In case of a short-

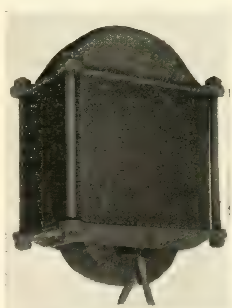

FIG. 3—LOW RESISTANCE IMPEDANCE COIL

circuit between the power and block rails, fuses protect the apparatus from injury. The resistance in circuit with the transformer secondary serves the further purpose of limiting the flow of alternating current when the rails are short-circuited by a train.

The type of alternating-current relay used with the single-rail scheme is shown in Figs. 5 and 6 and consists of a movable aluminum disc or section of a disc passing between the poles of a magnet. A part of the pole faces are enclosed by a closed conductor thus causing a distorted field which by the repulsion between it and the field set up by the eddy currents induced in the disc causes the necessary mechanical movement of the disc. The shaft upon which this disc is mounted carries contact parts (at a short radius) which operate to control other circuits which operate the signals.

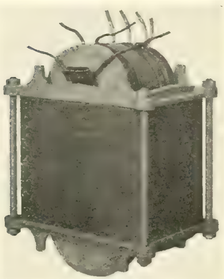

FIG. 4—TRACK TRANSFORMER WITHOUT CASE

When a block is not occupied by a train, the drop in propulsion voltage $D$ (see Fig. 1) is divided between $A$ and $B$ in proportion to the ohmic resistance of the apparatus connected across the rails at those points, the drop in the block rail being relatively negligible. This is the case also when a train is in the middle of the block. When, however, a train is at A, both the block and return rail are at the same potential at that point because connected by the wheels and axles, which also shunt the relay. Drop $D$ now appears at $B$, thus creating perhaps the most unfavorable condition for the transformer, for it now receives the maximum direct current from the track while delivering an increased amount of alternating-current. When a train is at $B$ the transformer receives no direct current and delivers the maximum alternating current. Simultaneously the relay receives direct current due to the total drop $D$, and it would not matter if its iron were saturated. for alternating current is not present because a train occupies the block, hence the relay is properly inoperative and the signal indicates danger.

The means provided to protect the track transformer and relay from the effect of the propulsion direct-current drop, limits to some extent the useful effect of the alternating-current in the track cir-

cuit. Clearly then there is a limit to the amount of direct-current drop under which an alternating-current track circuit of given length will be operative with the single-rail scheme. Fortunately this point has not been reached in practice, for a loss of energy in a rail return system sufficient to disable the alternating-current track circuit could not ordinarily be tolerated.

In the single-rail scheme the amount of alternating signal cusrent in the track rails is relatively small so that its drop in voltage between the transformer and relay is not serious. The insulation resistance between the block rail and return rail is another factor

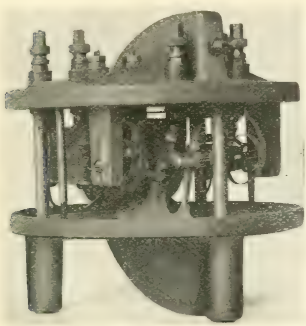

FIG. 5—ALTERNATING-CURRENT RELAY WITH GLASS COVER REMOVED

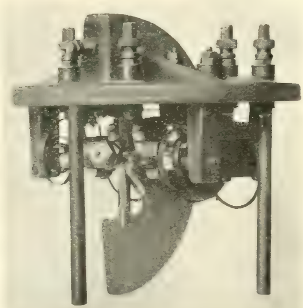

FIG. 6—RELAY WITH BASE REMOVED, SHOWING MOVABLE VANE

greatly affecting the operation of the track circuit. Not only does this decrease as the length increases, but it varies greatly with weather and other conditions. The expedient of increasing the transformer capacity to overcome leakage difficulties (occasionally as low as two ohms per thousand feet of track) is not wholly advantageous because increasing the alternating-current track voltage at the transformer increases in like proportion the leakage current from block to the return rail, and it increases the alternating-current drop in the rail because of this increased current, so that the relay is not greatly benefited. It is better to reduce the length of the track circuit where necessary, as that is more beneficial in every way. This does not necessarily mean that the block must be shortened for the track between the signals may be subdivided into a number of track circuits, each one of which controls the signal. It may be seen that the signaling equipment is in a sense a compromise

with respect to a number of conditions which are conflicting and which to some extent cannot be known in advance. Experience thus far has not presented track conditions requiring more than one track circuit between signals. A number have been in service more than three years which are about one mile in length and give no trouble.

APPLICATION OF THE SINGLE-RAIL SYSTEM

The most notable installation in which the single-rail alternating-current track circuit is used is that of the New York Subway. In this the automatic block signals, Figs. 7 and 8, automatic train stops, Fig. 9, and interlocking switch and signal plants, (the latter

FIG. 7—FRONT VIEW OF A TYPICAL BLOCK SIGNAL IN THE NEW YORK SUBWAY

signals being semi-automatic) are of the electro-pneumatic type. The track relays control circuits which in turn control magnetically operated pin valves governing the admission of air to the cylinders which actuate the signals and train stops. In this installation the two alternating-current signal mains carry current at 500 volts and 60 cycles. To these mains are connected the primary leads of the track circuit transformers which step down by one secondary winding to ten volts for supplying the track circuit, and by another secondary winding to 55 volts for the signal lights. The non-inductive resistance of one ohm between the track rails and the ten-volt sec-

ondary causes a drop of about two and one-half volts, so that the alternating-current potential across the rails opposite the transformer is seven and one-half volts. A similar resistance in series with the alternating-current track relay at the opposite end of the block causes an additional drop of two volts, reducing the voltage of the relay to about five volts which allows one-half a volt for drop in the rails. These values are only approximate.

The alternating-current energy required per block may be summed up as follows: That for the signal lights, the one ohm resistances and the leakage (from rail to rail), non-inductive, and that for the track transformer, the impedance of the rails, the track relay and the impedance coil connected across the relay terminals, partially inductive. The power-factor of the whole is about 80 percent and the load per average block with average traffic, 80 watts.

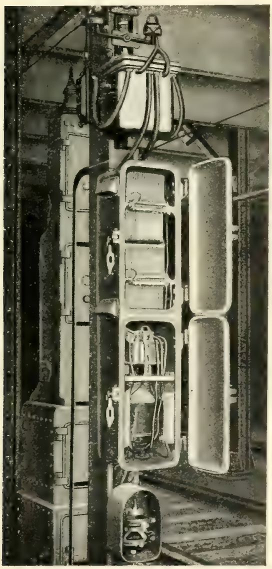

FIG. 8—SIGNAL APPARATUS—REAR VIEW*

In order to secure the greatest safety as well as density of traffic on the express tracks and at curves on the local tracks, the signals were placed at intervals as close as the braking distance of a train plus a reasonable margin of safety would permit. The element of personal error on the part of the motorman was eliminated by the automatic stops, Fig. 10, which apply the brakes when he fails to observe a danger indication of the signal. It has been found, however, that the moral effect of this train stop is very great, for no motorman will carelessly invite the censure of his employers and the public

*This figure shows the details of the alternating-current signals as applied to the Subway in New York. The track transformer is at the top. Beneath it is the instrument case containing the grid resistances, track relay and reactance coil. Below the case is the electro-pneumatic valve for controlling the automatic train stop.

by a non-observance of the signal thus made conspicuous by the noise of escaping air and the sudden stoppage of the train.

In such a case, the only question of veracity at issue is whether the stop was in the danger position while the signal indicated safety, a situation which exists when some part of the stop mechanism or its controlling circuits are deranged. To avoid serious delay to traffic when the stop apparatus is out of order, means are provided whereby a guard may hold the stop in the clear position while his train pulls over it, but as soon as this act of the guard ceases the stop returns to the danger position.

The remarkable record of performance of the signal system in the New York Subway is worth noting. The failures due to all causes, many of which are not directly chargeable to the signal apparatus, are about one to every 400 000 signal operations. Some months it is not so good while in others it is even better.

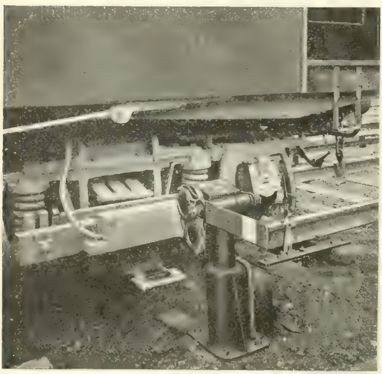

FIG. 9—DWARF SIGNAL AND AUTOMATIC TRAIN STOP

### ALTERNATING - CURRENT SIGNALING ON STEAM ROADS

Recent developments indicate that alternating-current signaling will have a large field on steam roads. This is primarily due to the trouble experienced with foreign direct currents, chiefly from trolley cars, which interfere with the battery current commonly used in the track circuit. For this purpose alternating current at a frequency of 25 cycles is most desirable because of the relatively low impedance in the line wires and track rails due to reactance. No inductive bonds at the ends of the track circuits are required; hence the necessary alternating current in the rails is limited to the needs of the track relay and leakage from rail to rail. By the use of a relay of special design requiring a very small amount of current to operate, the total current in the rails is so small as to cause but little drop, which permits of the use of a long track circuit.

Alternating-current signaling on steam roads lends itself readily to the wireless control of distant signals, without the use of permanent magnets and the danger of residual magnetism.

In this connection, it should be noted that with the alternating-current relay the shunting voltage is practically the same as the pick-up voltage. Incidental but important advantages of the use of the alternating current for signaling steam roads are that the signals may be operated and lighted by alternating current taken from the mains which supply the track circuit. Thus all batteries are eliminated as well as oil for the lights and the services of lampmen.

One two candle-power or four and one-half watt lamp per signal blade gives better illumination than the average oil light and it does not smoke the lenses, nor blow out. The lights may be allowed to burn continuously night and day, as it ordinarily would not pay to turn them off because of the small energy required and the long life of such lamps. The signals may be operated by induction motors (having neither brushes nor commutators) and the slot magnets likewise may be operated with alternating current.

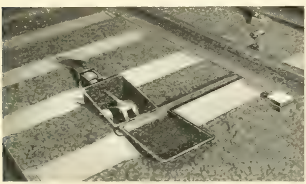

FIG. 10—DETAILS OF AUTOMATIC TRAIN STOP

The foregoing considerations, in addition to the chief advantage of non-interference of foreign current in the track circuit, are all in favor of alternating instead of direct-current operation. The weakness of the alternating-current system, however, lies in the possibility of disabling a number of signals due to breakage or crosses of the two wires constituting the signal supply mains.

High voltage wires are not desirable on telegraph pole lines, but if conditions permit the use of low voltage, say 500 volts, they may be placed on poles with other wires, but should be on the top cross-arm, so that other wires, which break more readily, may not fall upon and cross them. The best arrangement is to have an independent pole line for the signal mains if another high-tension pole line is not available, and make the construction so substantial that it will not break down. The stations supplying current to the mains should be equipped with apparatus in duplicate. By thus treating the equipment which is common to a number of signals with the same care that is bestowed upon electric power and lighting systems, this part of the signal system could be made reasonably reliable.

# THE TREND OF STORAGE BATTERY DEVELOPMENT

L. H. FLANDERS

IN CONSIDERING the development of storage batteries, two questions naturally arise: Why are lead plates with sulphuric acid the prevailing types of battery? Why does not development manifest itself along new lines using metals of higher capacity per unit of weight than lead? Experience and the present status of electro-chemistry indicate that there is very little probability of securing successful storage batteries unless the following conditions be met:—

First—That the metals and their salts which compose the plates be insoluble in the electrolyte.

Second—That when the plates are completely charged no decomposition of the electrolyte takes place with the exception of the breaking up of the water into hydrogen and oxygen.

It is true that other metals have been tried which dissolve on discharge and are redeposited on charge, but such plates have never been successful on account of the difficulty of controlling the metallic deposit. These two principles immediately narrow the choice of electrolyte to caustic potash or soda, and sulphuric acid. The first two have the disadvantage that they carbonate on exposure to the air. Furthermore, the alkaline electrolyte is only usable with cells of the so-called "oxygen lift" type such as the Edison battery. This type of cell has not reached commercial importance and, on account of the high cost of materials, the relatively low efficiency and the mechanical difficulties encountered in its manufacture, will probably have a very limited application, principally to electric vehicle propulsion.

In regard to the plates, lead is the only available metal which is insoluble in sulphuric acid, and this, coupled with the fact that lead peroxide and lead sulphate are also insoluble, accounts for the general use of the lead-sulphuric acid type of storage battery. Another cause tending to the further use of lead is that, next to iron, it is the cheapest available metal in the arts.

The development of the lead-sulphuric acid type of storage battery has been along two distinct lines.

First—Batteries intended mainly for stationary service.

Second—Batteries for vehicle propulsion.

Where storage batteries are to meet the first condition, life and

efficiency are the chief considerations and energy capacity per unit weight is not a deciding factor, while with the storage battery intended for vehicle propulsion, energy capacity per unit weight is the controlling element. Long life and energy capacity per unit weight are directly opposed to each other. In designing plates for stationary service, such a compromise must be made that the annual charge for the perpetual maintenance of the battery will be a minimum. This annual charge is made up of the interest on the investment and the maintenance expense for labor and material. By way of illustration—if a plate having too large a percentage of active material to total weight be used, the energy capacity per unit weight will be high, the first cost for a given capacity of battery will be low together with the interest on the investment, but the labor expense for maintenance, together with the cost of renewals, will be so high as to make the total annual charge prohibitive. On the other hand, if the energy capacity per unit weight is too low, the first cost and consequently the interest charges on the investment will more than offset the reduced annual maintenance expense.

In this article storage batteries designed for stationary use only will be considered, and the discussion of such an installation will be given in the following order:—

First—Plates.

Second—Electrolyte.

Third—Containers.

Fourth—Material for installation.

Fifth—Auxiliary electrical apparatus.

Sixth—Care and operation.

### PLATES

For the sake of clearness let it be understood that theoretically at the beginning of the discharge of a charged cell the elements consist of positive and negative plates in a solution of sulphuric acid. The positive active material is peroxide of lead which surrounds a supporting conductor. The negative element consists of spongy lead supported by a conductor. The sulphuric acid permeates the pores of the active material of the plates. During discharge the active material of the plates contains an increasing amount of lead sulphate and the electrolyte contains a decreasing percentage of sulphuric acid. At the end of the discharge the active material of both plates has been reduced to sulphate of lead and the electrolyte has been changed to water. The oxygen of the positive plate has combined with the hydrogen of the sulphuric acid to form this

water, the sulphate having combined with the lead of the active material. Thus both plates are lead sulphate and the cell is at zero potential. Upon charging, the reverse action takes place. The water in the solution is replaced by sulphuric acid formed from the sulphate liberated by the plates and hydrogen from the water, the oxygen of the water uniting with the lead of the positive plates. Theoretically, the battery is in the same condition after a discharge and recharge that it was at the beginning of the discharge.

From the foregoing, it might be inferred that the storage battery has no depreciation, but unfortunately, such is not the case.

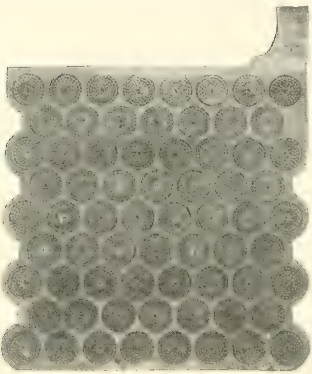

FIG. 1

*The Positive Plate*—Lead plates are of two types, the Plantè and the Faure. The Faure or pasted type is not used as a positive plate for stationary service in this country. While it is of high capacity per unit weight, the active material, which is in relatively large masses, softens and disintegrates more easily than the active material of the Plantè type where it is formed from the grid itself, and is in thin layers surrounding a conductor and accessible to the electrolyte. In the pasted construction, large masses of isolated sulphate may form which are inaccessible to the current and electrolyte so that great difficulty is experienced in keeping these plates in condition and, unless properly handled, they are liable to disintegrate rapidly. The one disadvantage in the use of pure lead Plantè positive plates is the growth or expansion of the peroxide which stretches the pure lead frame to which it is attached. This feature has led to the modified form of Plantè plate, (Fig. 1), in which the active portions are of pure lead surrounded by a containing frame of antimony lead. This hard frame will not distort and thus the growth of the pure lead pellets is restrained. In some plates, (Fig. 2), the active portions, in the form of biscuits two to three inches square, are attached to one side of the lead antimony frame, with open spaces between the biscuits and the other three sides of the frame to allow for their growth. In the plate shown in Fig. 3, the biscuits are attached at the two op-

posite sides of the antimony frame and are left free to expand at their ends. A grooved lead plate with a Plantè formation will grow in length, that is, in the direction of the grooves rather than transversely. Aside from the disadvantage of buckling or warping, which is liable to produce short-circuits between the adjacent plates, the integral pure lead plate possesses decided advantages over the composite type of Plantè plate. The futility of attempting to prevent the growth of the active portions of the plate has been recognized and, therefore, provision has been made for this growth so that it will take place within the confines of the plate itself. The buckling effect is thus confined to the individual section and does not develop in the plate as a whole. Such a plate, as shown in Fig 4, is of one piece of pure lead without joint or weld and, as a consequence, has a very low internal resistance. It is so constructed that all over the plate, the current and the electrolyte are equally accessible to the active material. It will be noticed that the plate is divided into thirty-six active portions consisting of longitudinal laminations, surrounding the surface of which is a thin layer of peroxide of lead. Between these biscuits and connecting them, is a corrugated sheet *AA*. As the plate

FIG. 2

FIG. 3

grows, the sections extend in length, thus closing up the corrugated expansion joints, but taking up the growth within the plate itself.

*Negative Plates*—The pasted type of negative plate is largely used, but possesses the disadvantage of requiring careful handling. On the other hand, the ordinary form of Plantè negative is exceedingly durable and will stand all sorts of abuse without mechanical disintegration. It will not, however, maintain its capacity, which drops in a few hundred discharges to from 50 to 25 percent of its initial value. The capacity may be temporarily restored by charging the negative to positive and back again to negative, or completely reversing it. This loss of capacity, tends to prevent the adoption of this form of Plantè negative plate. This loss may

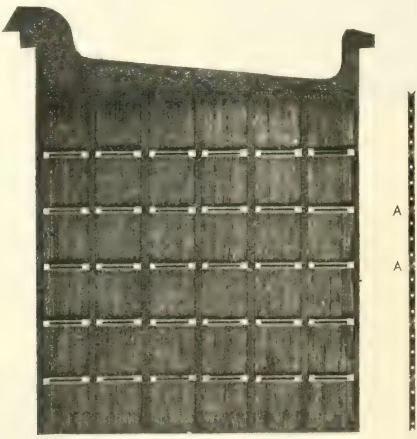


FIG. 4

be explained by the shrinkage of the negative material caused by the cohesion of the pure lead walls of the spongy lead mass constituting the active material. This will be appreciated when it is explained that the negative active material, when fully charged, is lead of the utmost purity and that any oxidization is prevented by the bath of nascent hydrogen given off when the plate is charged, and that clean surfaces of lead may be united by simple pressure. Due to the contraction and expansion of charging and discharging, the thin walls of some of the pores throughout the active mass collapse and stick together, thus reducing the porosity and consequently the capacity of the plate.

In a Plantè negative plate lately developed inert material has been introduced into the pores of the spongy mass, which has evidently prevented the collapsing and sticking together of the walls of the porous material, since the plates have a sustained capacity for an apparently indefinite time. Since there is no corrosion and disintegration in the Plantè negative plates, the lead conductors and supports are made lighter than in the positive plates and no provision is made for expansion.

ELECTROLYTE

There is little probability of any development being made in the electrolyte beyond increasing and maintaining its purity.

CONTAINERS

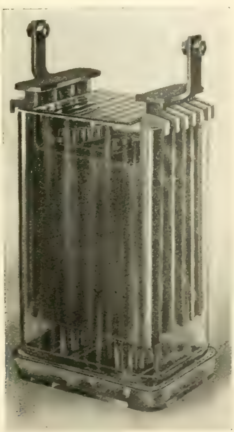

FIG. 5—ELEMENTS IN GLASS JAR WITH GLASS COVER AND INSULATING SAND TRAY

The most durable form of containers for stationary batteries are glass jars and tanks, but these are limited in size and are also liable to breakage during installation when of large size. Lead lined wooden tanks are used for elements that are too large for mounting in glass jars. These are very satisfactory, provided the wooden parts of the tank are kept clean and frequently painted. Efforts are being made to manufacture glazed earthenware tanks. If successful, these will prove absolutely permanent and, while their first cost will probably be somewhat higher than lead lined wooden tanks, the reduced maintenance charge will more than compensate for this increase.

MATERIALS FOR INSTALLATION

Too much care cannot be taken in seeing that the batteries are properly installed as proper installation is a large factor in reducing the maintenance expense. The plates should be adequately separated from each other. A new form of plate support is grooved glass, the edges of the battery plates being held in vertical grooves in these glass plates. In this way the plates are kept uniformly spaced and short-circuits around the plates are prevented.

Great care should be taken to secure proper insulation of the

battery cells from each other and from the ground. The heating and ventilating of the battery room is also of great importance. The available normal capacity of the battery, at the eight-hour rate of discharge, is reduced fifty-six one-hundredths of one percent for each degree Fahrenheit drop in the temperature below the normal seventy degrees.

When the surface of the tanks becomes coated with a film of sulphuric acid, this surface never dries, and the film must be removed by neutralizing with caustic soda. This action is explained by the fact that sulphuric acid, beyond a certain density, is hydroscopic and therefore will absorb water from the air. By using the exhaust system of ventilation, the sulphuric acid spray given off by gassing, may be withdrawn so that it will not precipitate, while if a blower is used, eddies of air will deposit the spray in a thin film over everything in the room.

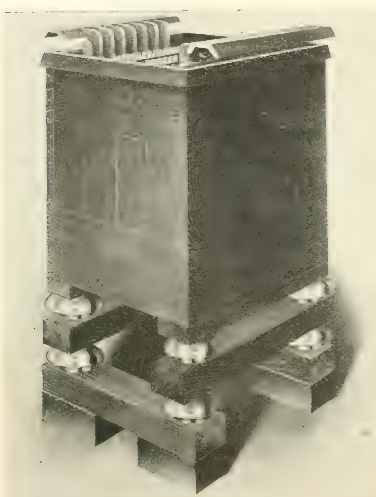

FIG. 6—ELEMENTS IN LEAD LINED WOODEN TANK

AUXILIARY ELECTRICAL APPARATUS

In order to secure the maximum value from a storage battery installation, the electrical auxiliary apparatus in the way of boosters, switchboards, etc., must be of ample capacity. Attempts to overwork the auxiliary equipment on over-load is "penny wise and pound foolish," as this part of the equipment, while it approximates only from ten to twenty-five percent of the total cost of the installation, is absolutely essential to its successful operation.

CARE AND OPERATION

A storage battery requires periodic, but not excessive care to secure the best results. Unlike engines, generators and motors, the storage battery, when abused, gives no audible and seldom any vis-

ible signs that it is not working properly, but continues to deliver current until it may be severely injured.

By using the specific gravity method of charging, that is, charging until the specific gravity of the electrolyte returns to the original value that it had at the beginning of the discharge, the efficiency and life of a battery may be much greater than when methods depending upon the voltage only are used. The specific gravity method is based on the fact that for each ampere-hour discharge, a definite amount of sulphuric acid is transferred from the electrolyte to the plates in the form of sulphate. Conversely, this sulphate is returned to the solution on charging. The change of specific gravity of the electrolyte is independent of the rate of discharge, so that knowing the change in specific gravity of the electrolyte for a normal discharge of the battery, the energy taken out at a varying rate of discharge can be determined at any time.

The persistent use of the auxiliary cadmium electrode to determine whether trouble is caused by the positive or negative plates should be encouraged. The use of distilled water for replenishing the loss in the solution due to evaporation and care in preventing impurities from getting into the cells should be insisted upon.

The storage battery, as now installed, is one of the most reliable pieces of apparatus available for the electrical engineer. The life of the negative plates is now indeterminate. The positive plates last from four to eight years, depending upon the service. Storage battery manufacturers make it a practice to enter into maintenance contracts with their customers, guaranteeing that the maintenance cost will not exceed from seven to ten percent of the cost of the battery for a period of ten years. Unlike other machinery, at the end of ten years, the installation will have the advantage of the latest developments in the art since, in renewing the plates, the latest types can be used. It is worthy of note that several millions of dollars have been invested in storage batteries by the prominent illuminating companies, these batteries being used simply for insurance against shut-down. They are only discharged when there is something wrong with the regular supply. At all other times they are kept fully charged and floating on the system. This shows the reliability and value of the storage battery of the present day in large power plants.

# SALES CONTRACTS—III

B. A. BRENNAN

### BAILMENT OR LEASE CONTRACTS

BAILMENTS or lease contracts are used in such states as Pennsylvania, for instance, where conditional sales or chattel mortgages are not recognized. A bailment is a rental contract—more clearly defined as a temporary transfer or a change in possession of the property without the passing of title—with a provision that the user is to retain the property for a certain time, paying therefor a specific rental, with the understanding that after a certain aggregate sum is paid the title shall then vest in the customer. The use of this form is quite remote in the practice of machinery manufacturers although quite common in connection with the sale of sewing machines, pianos, etc., etc.

### CONSIGNMENTS

Consignments cover such property as is usually in possession of a sales agent as his stock from which sales are made for his principal, but at no time does the title pass until actual sales are made; against said stock however no attachment can be made by said agent's creditors.

### CONTRACTS BY POST

Contracts and bargains are frequently concluded by written correspondence. An offer having been made through the mail, the proposing party may be regarded as tendering, by implication, the postoffice as his own messenger, to be used as a common agent for a response, and hence as awaiting reply by the bearer. Therefore, when an offer is made which requires the customer, either impliedly or expressly, to send an acceptance also by post, the contract becomes complete from the time the letter of acceptance is mailed or delivered, and to the same extent as though the acceptor had delivered the acceptance personally to the proposer.

The party to whom the proposal is made must, however, accept and mail his acceptance in due season, and before receiving any notice withdrawing the proposal. If the party making the proposal desires afterward to retract or modify it, he must communicate it to the party addressed before said party has mailed his acceptance; otherwise the proposer is bound, and if the party to whom the pro-

posal is mailed posts his reply of acceptance, the postoffice is the common agent and the bargain is complete, regardless of whether the letter finally reaches the proposer or not. But if the party to whom the proposal is made shall delay acceptance, and, meanwhile, notice of retraction of the offer reaches him before his own reply has been posted, the withdrawal takes effect, and there is no bargain. The proposer may, however, expressly stipulate that the contract is dependent on the actual receipt by him of the customer's acceptance.

The same application refers to offers by telegraph, and an offer without qualification becomes a complete contract by the simple depositing at the telegraph office of the acceptance.

### STATUTES OF FRAUD

As termed by the English law of 1678, the "Statutes of Fraud" was an Act for "Prevention of Fraud and Perjuries."

The purpose of the act was to exclude oral testimony in certain transactions, which should be supported by stronger evidence than the oral testimony of witnesses, and to preclude the danger of fraud and perjury and the mistakes possibly accruing from the imperfect and defective recollection of witnesses.

The United States has re-enacted the statute in whole or in part, but with so many variations in the different states that a decision in one state or jurisdiction is almost useless as a precedent in another. There are so many distinctions and questions as to prohibit a comprehensive view of the subject.

*Contracts for more than Fifty Dollars*—The object of this statute might be termed in another way, as a law to prevent litigation and fraud by requiring certain kinds of contracts to be made in writing, as relating in a general way to official acts of executors or administrators, marriage contracts, the sale and transfer of real estate, to agreements which cannot be performed within one year, and other contracts for the sale of chattels, namely, goods, wares or merchandise in value greater than $50. As relating to contracts of the character discussed in this work, we will treat two classes:

First—Agreements which cannot be performed within one year;

Second—Contracts of sale where the value is more than $50, (in some states $30).

*Agreements to be Performed Within One Year*—The English statute by the fourth section provides in part:—

"No action shall be brought upon any agreement that is not to be performed within the space of one year from the making thereof, unless the agreement upon which said action shall be brought, or some memorandum or note thereof, shall be in writing and signed by the party to be charged therewith, or some other person thereunto by him lawfully authorized."

That is to say, this act (not in force in Pennsylvania, North Carolina and Louisiana) means to include any oral agreement which by a fair and reasonable interpretation of its terms, considering all the circumstances existing at the time, does not permit of its performance according to the intention and its language within one year from its date. In other words, an oral agreement can be made void if it can be shown that the parties at the time of its making understood that it was not to be performed within one year, or that performance within one year was clearly impossible; as if by any possibility it could be fully performed within the year it is valid. For example, an oral contract made January 1st, for a year's service to begin May 1st, is obviously incapable of performance within a year from its date, and cannot be enforced unless the same is in writing; although where services have been rendered under such an agreement, whether covered in writing or not, the same can be recovered for.

The seventeenth section of the English statute provides that:—

"No contract for the sale of any goods, wares or merchandise for the price of 10 pounds Sterling or upwards shall be allowed to be good except the buyer shall accept the price of the goods so sold and actually receive same, or give something in earnest to bind the bargain, or in part payment, or without some note or memorandum in writing of the said bargain be made and signed by the parties to be charged with such contract, or their agents thereunto lawfully authorized."

That is to say, contracts to the value of $50 or over, (in some states, e. g. Maine and New Jersey, the amount is $30), the same must be in writing, or the buyer must give proof of his agreement by accepting or receiving a part of the goods or by a part payment on the same.

Labor contracts are not included in this statute.

### PROMISES AND AGREEMENTS NOT CONTAINED IN CONTRACTS

A salesman, in the sense applied to machinery, is usually authorized to do the specific thing of selling the machinery to his customer; the order, however, usually qualifies that it shall not be binding on his principal or firm until approved in writing, or, if a corporation, by its executive officer, at his or its home office. Unless a seller or manufacturer shall in some positive way notify the customer the limit of the authority of his salesman he may be bound to the full extent of the salesman's acts; for a principal is responsible

for the acts of his agents, not only when he has actually given full authority to the agent to act for him, but when he has, by words or acts, or both, caused or permitted the person with whom the agent deals to believe him clothed with this authority; and if the agent transcends his actual authority, but does not act beyond the natural and usual scope of business, the principal is bound, unless the party with whom the agent dealt with knew the agent exceeded his authority. We have explained elsewhere that in the construction and interpretation of contracts it is permissible to submit evidence as to contemporaneous oral agreements which supplement and explain the terms of a contract; that oral evidence is admissible to identify the subject matter, and we recall that the first and principal rule to be followed in the construction of contracts is to ascertain the real intention of the parties at the time the contract was signed. Imagine, and as is almost invariably the case, a salesman at a place, far remote from the home office or place of business of his principal, entering into a contract, the performance of which was predicated on some local condition, the nature of which his principal did not nor could not know, and suppose the salesman, in good faith, and to the best of his judgment, gave certain verbal advices. Later, the contract would reach his principal, and he, presuming that the instrument covered the entire agrement, would ratify it. The obvious result and far reaching effect of such instances has imposed on the manufacturers the necessity of restricting the authority of their salesmen in the proposal itself, so that when the contract reaches the principal it shall constitute the entire agreement. Two clauses are used:—

First—"It is expressly understood and agreed that there are no promises, agreements or understandings outside of this contract with reference to the subject matter; that no agent or salesman has any authority to obligate this Company by any terms, stipulations or conditions not herein expressed, and that no modification of this contract shall be binding on this Company unless the same be in writing and approved by an executive officer."

Second—"This contract is for immediate acceptance, and although so accepted it shall not be binding on this Company until approved by its executive officer at ......."

The second clause permits the manufacturer either to accept or reject the order after its receipt at the home office, and, obviously, is a desirable provision to include, as it gives an opportunity to review all of the contract conditions; the question of shipment; the warranties in the contract; the terms of payment; and, in fact, every opportunity is afforded for a consideration of the whole matter before ratification.

*Impossibility of Performance*—If the vendor in stipulating a date of shipment or completion of certain work makes the same conditional on its continued possibility, the vendee, or customer, takes the risk; if, on the other hand, the seller undertakes, by contract, to ship the complete apparatus unconditionally, he takes the risk of being held liable, even though the performance should become impossible by circumstances beyond his control, and in no case is non-performance of contract excused by the act of God where it may be substantially carried out, even though the act of God makes a literal performance of it impossible. The law holds that a man is not obliged to undertake a burdensome, dangerous, or unreasonable thing, but if he does, he must fulfill his agreement. If he cares to protect himself from such things turning out so, he has to provide for it in the contract. In other words if he promises unconditionally, he is bound unconditionally. In a certain case a contractor agreed to build a school for the plaintiff, and when nearing completion the structure was destroyed by lightning, but it was held by the court that this did not relieve the contractor from non-performance. In another case a railroad company agreed to carry certain goods from one point to another within a certain time, but failed to do so in the time agreed upon; the road contending that a public canal, which was intended to be used a part of the distance, became impassable by an unusual and unexpected freshet, but the case was rendered against them; and so, for reasons of this kind, we find that vendors invariably supply provisions in contracts, reading:—

"This contract is contingent upon strikes, fires, accidents, or other delays unavoidable or beyond our reasonable control."

*Foundation Work*—It is sometimes the case that manufacturers are compelled to take a contract for the complete erection of machinery, including the furnishing of the foundations for it. In reaching the contract price, the foundation work is included, usually based upon the estimate of cost for same on the assumption that the soil will be found suitable for the masonry of usual dimensions. It not infrequently happens, however, that difficulty is encountered in the soil, and to safeguard himself against such contingency it would be well to qualify the specifications as to the character of the foundation by the following clause:—

"It is understood that the soil will be found suitable for the reception of our masonry, our expense in preparing the foundations being confined to the mere digging and removing of dirt. Any blasting, cribbing, piling, shoring or other preparation for our masonry beyond the excavating herein specified

is to be done by you at your expense. It is also understood that if because of improper soil the character and dimensions of our masonry herein stated are seen to be inadequate the extra expense of the change thereby necessitated is to be borne by you."

*Guarantee of Performance with Option to Reject*—In the exceptional case customers insist on guarantees of performance coupled with an option to reject the apparatus if, on test, the same shall prove incapable of fulfilling the warranties of the contract. Such a clause, however, has the fault of inviting the customer's dissatisfaction, but, after all, amounts to no more than is implied by the contract, and its use can be applied in such a way as to limit the vendor's liability. The following clause is suggested:—

"It is understood that if the apparatus herein contracted for shall prove incapable of fulfilling the warranties herein expressed, you are to have the option of returning the apparatus to us, f. o. b. cars our works, in good order and condition, ordinary wear and tear excepted; we to return to you any and all sums paid by you on account of this contract; it being agreed that such delivery by you and the refunding of such sums by us shall constitute full and final settlement of any and all claims whatsoever between us on account of this contract, and shall restore both of the parties hereto to the position originally held by them had not this agreement and contract been made."

### SELLER'S REMEDIES

When a contract of sale is broken by a buyer, and where the transfer of the property has not taken place, and the property and possession remains still in the seller, his remedy usually becomes reduced to the question of damages sustained by the breach, and while, perhaps, equity might be invoked to enforce specific performance, this course seems rarely taken, because, in most cases, damages at law will afford adequate compensation. The damage which the seller actually sustains under these circumstances, and for which the law will compensate him is, in general, the difference between the contract price and the market price of the goods at the time and place of the breach, and, in addition, the reasonable cost and charges incidental to reselling in the market. In other words, such damages as will place the seller where he would have been had he been allowed to complete the contract.

In some states the seller is given the choice of three remedies in such cases:

1st—To sell the thing upon behalf of the purchaser upon notice to him, and recover the difference between the contract price and that realized upon the sale.

2nd—To retain the thing as his own and recover the difference between the contract price and the market price at the time and place of delivery.

3rd—To hold the property for the purchaser and recover from him the entire purchase money.

*When the Transfer of Property Has Fully Taken Place*—When the transfer of property has fully taken place the seller cannot sue in any special capacity, but is left in the position of a mere creditor, and nothing remains but for him to sue for his price, but with no better hold on the goods than any other general creditor. The title having passed, the goods are now the buyer's, and are a part of his general assets. But the seller, being thus driven to sue, may recover in a personal action the price promised, the accrued interest, and the costs of the suit.

*Contracts for Articles of Special Character—Made to Order*—The remedy mentioned under "Seller's Remedies" for damages on refusal of the buyer to accept the goods contracted for, namely, the difference between the contract price and the market value, will not always afford sufficient compensation in the certain cases where the articles contracted for are of a prescribed measure, style or pattern; in other words, made to order. And the measure of damages in such cases is usually held to be that where an article has been completed the full contract price can be recovered; where not completed, but work has been done and expense incurred, in addition to the difference between what would have been the cost of making the article and the contract price, the seller may also recover the direct damages sustained on account of the work already done under the contract.

Nor is the seller forced to await recovery until he can re-sell the article, as by it he might be compelled to wait in finding a market until the customer might have become irresponsible. Moreover, the article might have no market value or any value at all to any person other than the one ordering it.

Neither will the law compel the seller after refusal or countermand of the work to go on and complete the article before he can recover for the work already done, but he may treat the refusal or countermand as a prevention of performance and sue upon the contract.

## BUYER'S REMEDIES

*Breach of Contract and Damages*—The question often brought forcibly to the minds of sellers is their liability for delays, and occasioned frequently by the customer's demanding deductions of sums to pay for their hurts or for delays in shipments, etc. When a contract has not been fully performed, or has been broken, it either may

have resulted from a mutual disregard of the contract, or it may result in the right of action by the injured party for damages, or the right of action to enforce the contract.

When a contract of sale is broken by the seller it usually falls within the following category:—

1st—Where the seller fails altogether to deliver:

2nd—Where delivery is made or tendered, but the thing is not in kind, quality or quantity that was contracted for:

3rd—Where there is unreasonable delay in delivery.

*Where the Seller Fails Altogether to Deliver*—The common remedy in such cases is by personal action against the seller for damages, and the measure of damages is, in general, the difference between the price contracted for and the market price at the time and place where delivery was to be made.

A buyer, however, in case the title has been transferred to him through the nature of the contract may either seek a money recompense, or may insist on getting the goods and enforcing his claim of ownership; that is, as refers to the sale of chattels, such as statues, paintings, antique vases, or such articles as the buyer could not be made whole for, by going to the law for damages.

In cases, however, where the article contracted for is of a special character, and cannot be found upon the market, or if it can only be produced at a greater price than the contract sum, the buyer has the right to recover the difference between the contract price and the actual price necessary to obtain the article.

Where an article contracted for is special, and there is no ready market, such that the buyer cannot supply himself upon the market, he may recover the amount lost by reason of not receiving his advance in price or profit through agreements which he has made depending upon the fulfilment of the contract, or likewise, the amount reasonably spent by him to avert impending loss because of the non-delivery of the article which is not procurable.

*Where Delivery is Made or Tendered, but the Thing is Not in Kind, Quality or Quantity that was Contracted for*—The remedy of the buyer depends almost entirely upon the law in the particular state. In most cases, however, the buyer may consider the warranty as a condition subsequent upon breach of which he may repudiate the contract, or he may, at his option, and on notice to the seller, keep the goods and resort to money compensation in damages for the seller's breach of express or implied warranty.

The leading principle of the law of warranty at common law is that the purchaser buys at his own risk, but when the seller has given an express warranty this doctrine fails of application.

WARRANTY

A Warranty is an express or implied statement of something which the seller undertakes as a part of the contract. Warranties are usually treated under two headings:—

1st—*Express Warranty;*

2nd—*Implied Warranty.*

*Express Warranty*—An express warranty is one where the seller actually assures the buyer, either verbally or in writing, of the existence or non-existence of a fact at the time of sale in such expressions as "I warrant the goods", "I guarantee the goods", specific guarantees of quality, etc., etc.

*Implied Warranty*—An implied warranty is that which the law deduces and enforces from the contract, or based upon the actions of the seller at the time of the sale, or arising from the sale itself.

*(To be Continued.)*

# THE DIRECTION OF INDUCED CURRENTS *

H. L. KIRKER

VARIOUS schemes have been devised to aid in remembering the relations between direction of induced current and motion of a conductor in a magnetic field. In one of these, Ampere's rule,† the analogy of a figure swimming in a current is used; in another, Fleming's rule,‡ the relations are given by placing the thumb and first two fingers of one of the hands in certain positions. Personally the author never liked Ampere's rule nor did he find Fleming's rule quite satisfactory. There was always the liability of forgetting the position of the swimmer with relation to the magnetic needle and it was difficult to keep in mind which finger of the hand corresponded in direction to lines of force, motion, etc.

It was not difficult to remember that parallel currents flowing in the same direction attract one another and flowing in the opposite direction repel. Likewise there was no difficulty in grasping the assumption that current is encircled by rotating lines of force and that the relation of the direction of the magnetic lines to the direction of the current in the wire is that of right hand rotation and forward travel of a corkscrew. Starting with these simple assumptions concerning the magnetic properties of currents, the author found (some twelve years ago) that, if he assumed the encircling magnetism to be a magnetic whirl or vortex and, if these encircling lines came into the neighborhood of another wire, they held back from jumping across the wire, thus forming a bend or dent in the vortex, which dent became an incipient vortex around the neighboring wire, an immediate indication was given of the direction of induced current.

For example, if a current is sent down the main wire in Fig. 1 a magnetic vortex is set up around the wire. As the vortex enlarges

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*Revised from an address given before the Grand Trunk Literary and Scientific Institute Apprentices, Port Huron, Mich., Dec. 7, 1906.

†"If one imagine himself swimming with the current and facing the needle, the north seeking pole will always be deflected toward his left hand."

‡"Let the forefinger of the right hand point in the direction of the magnetic lines; then turn the thumb in the direction of the motion; the middle finger bent at right angles to both thumb and forefinger, will show the direction of the induced e. m. f."

it strikes the neighboring wire and forms a dent as shown. If, now, this dent in the expanding vortex is considered as the beginning of a vortex around the second wire, the direction of rotation of this incipient vortex is counter to the main vortex. In this particular case

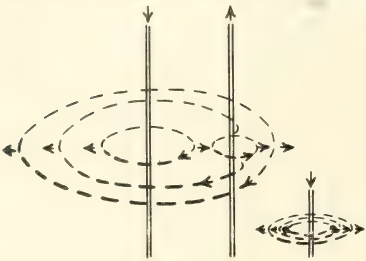

FIG. 1

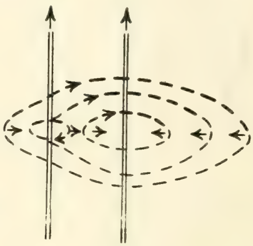

FIG. 2

the direction of the magnetic whirl around the main wire is clockwise and that around the second wire counter-clockwise, which means that the main current is flowing down and the induced current up.

If the main current is interrupted it may be seen by referring to Fig. 2 that the contracting vortex is dented out when it encounters the second wire. If, as before, the dent is considered as an incipient

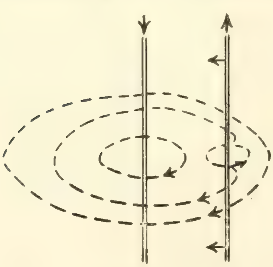

FIG. 3

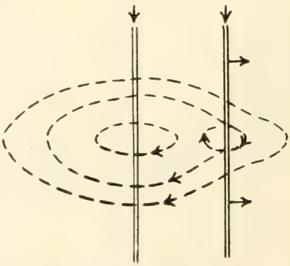

FIG. 4

vortex it will be seen that the direction of rotation is the same as the main vortex, which means that the induced current is flowing in the same direction as the main current.

Likewise, if it be assumed that a steady current is flowing in the main wire and a second wire is brought near, as in Fig. 3, the direction indicated by the dent shows that the induced current is opposite

to that in the main wire. Also, if the second wire is moved away, as indicated in Fig. 4, the dent shows that the induced current is in the same direction as the main current.

If in addition to the assumption that a wire carrying a current is the axis of a magnetic vortex, it is assumed that neighboring vortexes rotating in the same direction tend to merge and those rotating in the opposite direction tend to push apart, a simple mental picture may be obtained of the attraction of parallel currents flowing in the

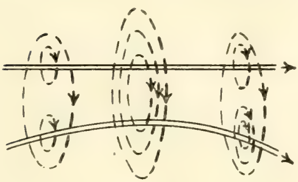

FIG. 5

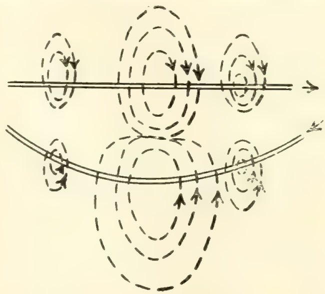

FIG. 6

same direction (see Fig. 5) and the repulsion of those flowing in opposite directions (see Fig. 6).

In general, this assumption of the magnetic whirl can be used to explain the inductive and magnetic properties of electric currents. The direction of the curved dent made by the wire in the neighborhood of a vortex shows which way the induced current flows, and the relative direction of the two whirls shows whether the currents attract or repel one another.

# EXPERIENCE ON THE ROAD

## UNEXPECTED SHOCKS

H. I. EMANUEL

DURING a recent process of changing a steam road to electric traction some wood frame cars were being overhauled and equipped as trailers. While some workmen were engaged in installing the rods and brake rigging upon these cars one of them complained of having received an electric shock. An examination showed that the brake rigging which he was handling was connected to the truck which was, of course, grounded, so it was supposed that the man was mistaken. After a few minutes a second man complained of a shock and a more careful examination was made. It was found that the brake rigging which he was handling was not only connected to the rail through the truck but that no trolley wire was in that part of the shop nor did a wire of any character lead into or even near the car and yet it was evident that both of the men were not mistaken. A few minutes spent in watching the case revealed the cause of the trouble. The rails beneath the cars were not bonded and a joint occurred in each rail between the trucks. These joints were rusty and the fish plates and bolts not tight. The track ran through the shop to a dead end and some movement of cars was taking place on this track beyond the trailers. The brake rigging that was being put up by the men was connected some to one truck and some to the other but none of the rigging happened to connect the two trucks together. It is evident that with an unusually bad joint at this point there would be a difference of potential between the two trucks equal to the drop at the rail joint and anyone touching the brake rigging of the two trucks or the brake rigging of one and the rail beyond the joint would receive a shock equal to that potential, which in this case was sufficient to frighten even if not to hurt.

THE
# ELECTRIC JOURNAL

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**The Illumination Situation**

The last few years have made great changes in the art of artificial illumination; not only has there been a great increase in the number and efficiency of available light sources but also a great advance in the methods of their utilization. Furthermore, this art has become greatly specialized. Methods of illumination and types of lamps well adapted to one installation will usually be entirely unsuited to an installation of a different character. But it is notable that in all directions a great gain of efficiency has been accomplished.

The article by Mr. Stephens in this issue of the JOURNAL describes the latest development of electrical apparatus for street illumination. This particular field of lighting has heretofore been a difficult one for central station managers to handle. To get the advantage of the greatly superior direct-current arc lamps, it has been necessary to utilize a large number of small generators of relatively low efficiency which, as Mr. Stephens explains, has been awkward and uneconomical. Furthermore, as it has not been found practicable to run any of the types of alternating-current arc lamps on twenty-five cycles, a great many plants have been unable to utilize the series alternating constant current arc, which is a compromise that has sometimes been found desirable.

The apparatus here described is an especially happy solution of the problem of street lighting from central stations, since it is both very efficient and most readily adaptable to any commercial frequency, including twenty-five or even fifteen cycles. It means practically not only a reduction of something like forty percent in the consumption of the lamp itself but further the operating of the best type of direct-current street arc lamp directly from the main constant potential bus-bars of the central station without the introduction of rotating apparatus. It also secures the great economy and

simplicity of distribution characteristic of the constant current system.

On the other hand, this system is not at all adapted to interior illumination, partly on account of the high tension of the circuit, partly because so many lamps are required in a series to make the regulator and rectifier economical and partly because of the fumes from the lamps. Fortunately, however, for interiors we have other relatively new types of light sources; the Nernst, the tantalum, and the tungsten lamps, where the best color quality is combined with efficiency, and where even diffusion, absence of shadows, working quality, and economy are paramount, the Moore lamps, and the much more efficient Cooper-Hewitt mercury vapor lamps.

There remains to be enumerated among the recent developments also the metalized filament lamps, which are the old standard incandescents with an improved efficiency, and the flame carbon or Bremer type arc lamps, which have perhaps the highest candle-power efficiency of all, but which are available only for advertising, outdoor illumination and for very large covered spaces, on account of their great brilliancy, the relatively large quantity of fumes they produce and the very expensive and short-lived carbons used.

This imposing array of new electric lamps, taken in connection with the improved types and forms of reflectors, diffusers and screens for concealing light sources, and with the recognition of the importance of light colored ceilings and walls, show what a remarkably rapid progress has marked the recent history of the art of electrical illumination.

Percy H. Thomas

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**Alternating-Current Block Signaling**

The article by Mr. Struble, in this issue of the Journal, describing the application of alternating current to the signaling of railroads is of peculiar interest at this time to the signal engineer, to the electrical engineer connected with railroad work, and to the student of general engineering progress. They possess the most vital interest for the first. Almost all railroad managers are studying their traffic conditions with a view to answering the question, "Will electric traction enable us to pay larger dividends?" The signal engineer may at any time be asked what change will be made necessary in his signaling system if electric traction is adopted, and what expense the change will involve. He is not by profession an electrical engineer, but as the

one responsible for the signals he has to make a choice, requiring considerable electrical knowledge, from various systems and types of apparatus, of that best suited to operate the signals under the conditions which the change to electric traction will impose. A new opportunity is offered him of proving his right to rank with engineers in other lines, and of securing recognition from his own superiors as one of their most important operating officials.

To the electrical engineer the articles disclose a special branch of electrical engineering, in which is involved the design of varied forms of induction apparatus, in which neither short-circuits, nor open circuits, nor mechanical defects may be permitted under any circumstances to give a false safety signal, and the efficiency and first cost of which, when combined in a signal system, vary with the efficiency of the return system of the traction installation.

It is important to note, finally, that while the traction engineer, with his new propulsion forces, has created new danger elements in signaling, the apparatus designed to meet the new conditions has done it so efficiently that even safer and more efficient signaling is promised for the future than was possible in the past, on steam roads as well as on electric roads. L. FREDERIC HOWARD

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**The Man and the Organization**

Happiness and success depends in a large measure upon the relation which exists between the individual and his fellows, and, in modern commercial life, between the man and the company or organization of which he forms a part. Too often the man regards the company as a sort of enemy, from which he is to get the maximum return for the minimum labor. Too often the attitude of managers is that of the slave driver who seeks results by compulsion and severity.

What is the correct philosophical relation between the man and the organization which will insure individual freedom, initiative and interest on the one hand, and which will, at the same time, bring the most efficient results from general co-operation through system and organization in a large corporation?

This question, which so vitally concerns the success both of the individual and of the company, is treated in the admirable article on "Man-Power" by Mr. Frenyear in the JOURNAL for March, 1904. After pointing out the necessity of having leaders who are men of ability and of power to direct our energies, the question is put as to how this executive control may be exercised in order to

be effective and yet not at variance to the principles of modern democracy nor subversive of real freedom. The true principle of organization in a democratic community is thus set forth:—"Getting others to do what you want done while they are doing what they themselves wish to do. Inspiring others with a desire to do what you want done, not driving them to do it. Knowing men, setting before them the objects of their ambition and affection in the line of your own purposes."

This same principle is again set forth in an address by Mr. John T. Hayford in the present issue of the JOURNAL. This address puts in clear and admirable form the relationships of the engineer to his surroundings in the successive stages of development, and it presents so clearly what may be termed the human side of the modern organization that it appeals both to those who are engineers and to those who are connected with a large organization in any capacity.

The same idea is put in a little different form by Mr. E. M. Herr, when he said in an address before The Electric Club, "It is of first importance to get the right spirit, so that every fellow is pulling the right way and pulling hard. No big man can himself alone do much in a big organization, it is united individual effort which produces results."

CHAS. F. SCOTT

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**Standard Tests for Dielectric Strength**

The Standardization Rules recently adopted by the American Institute of Electrical Engineers have been very considerably modified and amplified, particularly that part referring to dielectric strength. This modification has been, first, to secure a more logical arrangement of the subject matter with headings which allow of the more ready finding of any particular points incorporated in the Rules; second, to give more accurate definitions and instructions for the carrying out of any particular class of tests. The rules are intended to cover general commercial work but special cases may be found where it is desirable to use modified tests, such modification being subject to mutual agreement between the manufacturer and the consumer. The table of testing voltages adopted in 1902 has remained unchanged with the exception that no test is now less than twice the normal rated voltage, whereas the former rules allowed a lower test on voltages above 10 000 normal. The time of the application of dielectric tests, of one minute, remains unchanged.

Among the important features is the definition of Rated Terminal Voltage. In most cases the meaning of the term is obvious, but the definition given will do much to clear up the uncertainties and different interpretations which sometimes existed. This definition together with the specific cases enumerated should usually make it clear what test should be used, whether the apparatus is connected across the circuit or in series with the circuit, whether it be a shunt transformer, a series transformer, a line switch, a cable or an ammeter. By a specific definition transformers for use on three-phase star-connected systems are required to be tested on the basis of the delta voltage. It is, of course, possible that a "graded" test might be satisfactory for three-phase star-connected transformers, where the neutral of the system is permanently grounded. To secure such a graded test the test voltage, as determined by the delta voltage, should be induced in the transformer under test and the "line" end tested by grounding the "ground" end and then a lower voltage used for the test with "line" end grounded. It is usually better, however, to give such transformers the standard test so that either end may be connected to line as required.

The rules are evidently intended to cover usual conditions as it is specifically stated that the tests recommended are those which experience has shown to be reasonable and proper for the great majority of cases and are proposed for general adoption except when specific reasons make a modification desirable. Particular or peculiar conditions are apt to arise in which a rigid and literal application of the rules would be absurd and not in accord with their principles and spirit. For example, it would be quite stupid to insist on testing a 250 volt single-phase railway motor at 20 000 volts simply because there is metallic connection between the motor windings and a 10 000 volt trolley wire through the auto-transformer on the car. One terminal of the motor is permanently connected to the ground, making it a matter of indifference to the motor insulation whether the trolley e.m.f. be 500 to 10 000 volts.

Two different classes of tests are introduced, these being in accordance with methods which have come to be more or less general practice. The reason for these classifications is mainly the convenience of being able to make tests quickly where this is permissible, as in apparatus having small static capacity, in which case the sudden switching on of the full test voltage causes little or no rise of potential across the testing circuit. In case of very large static capacity there may be very considerable surges, due to the flow of

condenser currents in the testing circuit—as in the case of testing a long lead-covered cable—thereby causing a sudden rise of potential and abnormal strains where such were not intended. Definite figures in regard to the exact limitations of the two classes could hardly be given at this time, but it is hoped that these may be more definite by the time it is again necessary to revise the rules.

Considerable additional matter has been added to the rules with reference to the conditions and precautions necessary in applying dielectric tests. It is well known that the dielectric stress varies with the maximum of the electro-motive force wave instead of with the square root of the mean square, and consequently, any modification of the wave form will give a direct modification of the stresses applied, hence the precaution given to preserve as nearly as possible the sine wave in the testing circuit. The spark gap is the only means given of measuring the test voltage, which shows maximum values of the e.m.f. wave.

Under the heading "Transformer Coils" some special precautions are given, such as connecting the low tension winding to the line and case during a test of the high tension winding to ground, and the connecting of the various windings together. These precautions are inserted as a result of some sad experiences by those framing the rules. In the writer's own early experience some very expensive breakdowns occurred from the low-tension winding to the ground during tests from high-tension winding to ground, due to the induced charge on the low-tension winding as one plate of a condenser discharging to the core through the weaker insulation usually provided for the low-tension winding. In another case while testing a very large transformer, the breakdown of the terminal bushing of the testing transformer resulted in surges in the high-tension winding, which short-circuited the windings to such an extent that complete rewinding of a number of coils was necessary. That part of the rules, relating to "Methods for measuring the test voltage" and "Apparatus for supplying test voltage," deserve careful study on the part of those who have such work to do. Space forbids an elaboration of the many points condensed into this single page.

The parts of the rules referring to insulation, as revised, are in very much more satisfactory shape than the previous rules and it is hoped that they will be generally followed.

C. E. Skinner

# METALLIC FLAME ARC LAMP*

C. E. STEPHENS

UNTIL within recent years, in electrical apparatus in general use for producing light, the actual energy given off as light was a very small percent of the total energy consumed. The lighting efficiency of this class of apparatus was ridiculously low when compared with the efficiencies of the electric generator or motor. Scientists have shown that the production of light is only a secondary result to the production of heat. The electric energy is radiated, only a very small part of this radiation being visible. Any achievement, therefore, which will raise the efficiency of light production, and provide means which will insure the commercial application of this greater efficiency, will be very acceptable to electrical men and will be watched with great interest.

The advent of the high efficiency incandescent lamps, and the improvements in gas lighting fixtures in the last few years have made it necessary to effect marked improvements in the efficiency of arc lamps if they are to retain their superiority.

The light emitted by a carbon arc is produced by raising the temperature of a carbon substance by sending electric energy from it into another substance. The larger portion of the light issues from the incandescent crater of the *positive* carbon, and since the higher the temperature, the greater the light efficiency of any incandescent body, the crater of the carbon arc is the highest efficient source of light by incandescense. Numerous experiments have been tried, in order to increase the efficiency of the carbon arc. Raising the temperature of the arc by using carbons of small diameter, thus reducing the heat conductance, resulted in a higher light efficiency, but decreased the life. The enclosing of the arc in an almost air-tight globe resulted in a lower light efficiency, but it had a great advantage, in that it insured a steadier light, greatly reduced the consumption and cost of the carbons, cost of trimming, etc.

There are, however, methods of increasing the light efficiency by producing luminescence of the arc. Lamps have been made which burn the so-called flame carbons; that is, carbons which contain a compound of calcium or other chemicals. This compound is usually

*From a paper presented before the Illuminating Engineering Convention, July 30-31, 1907.

placed in the positive carbon and since its boiling point is lower than that of carbon, it is evaporated out of the positive carbon, the vapor enters the arc, becomes luminescent and thus produces light of very great brilliancy. It is absolutely necessary that the arc have a high temperature, if a high light efficiency is to be maintained, since the brilliancy of the arc depends entirely upon the amount of the luminescent vapor, and this in turn upon the temperature of the positive carbon. Lamps of this type produce large quantities of fumes and smoke, the disposal of which necessitates an open burning condition. Thus, the high efficiency of this arc is due entirely to the high temperature. A high temperature together with the fact that it must be an open arc means a rapid consumption of carbon—life is thereby sacrificed for efficiency.

Years of experience in artificial street illumination have clearly shown that the majority of people demand a white light. The most efficient lamps of the flaming carbon type emit a yellow light, and as yet a carbon has not been produced which will give a white light, except at a greatly reduced light efficiency. The efficiency of a flaming carbon arc giving a white light is not sufficiently superior to that of the enclosed arc to offset its many disadvantages, and it is not reasonable to suppose that a flaming carbon arc giving a yellow light will have a larger field than that of advertising, decorative, or other purposes, where the disadvantages of a short life, smoke, excessive brilliancy, and poor distribution are not objectionable.

The high efficiency of the metallic flame arc lamp is obtained by using for electrodes a material, the vapor of which not only serves to carry the current but possesses the property of selective radiation and is the source of a brilliant and highly efficient spectrum. It is also desirable to use for electrodes a material which is not affected by the air, and gives a spectrum approaching that of daylight. Several years of experience have proven that the oxide of iron is the best material for the negative electrode. Although it is not very efficient as a producer of light, it is a good conductor and is very stable at all temperatures. The performance of the iron oxide in a metallic flame arc is similar to that of carbon in the flame carbon arc; that is, it furnishes a conducting vapor and the highly efficient light is produced by the addition of titanium. In the metallic flame lamp the arc vapors are furnished by the negative electrode. Since the volume of vapor produced would be more than is absolutely necessary, it is desirable to add some material to restrain the evaporation of the material. The oxide of chronium has been

found to be a suitable material to limit this volume to an amount necessary to carry the current. The volume of this vapor does not depend upon the temperature, and it is possible to maintain a highly efficient arc at a comparatively low temperature—thus decreasing the consumption of the electrode. The positive electrode of this type of lamp is usually made of metal or an alloy of ample size to properly radiate the heat and whose oxides, when fused into a slag, will be a good conductor when cold.

The life of one trim of electrodes for the metallic flame lamps will average 165 to 170 hours; however, the life can be increased by sacrificing efficiency, or can be decreased with the corresponding increase of light efficiency, all depending on the proportion of the light-giving material used in the electrodes.

The arc produces a uniform white light of very great brilliancy. Unlike the carbon arc, practically all of the light is emitted from the arc instead of the carbon tips. It closely resembles that of a candle flame, having a bright and non-luminous zone. The bright zone is contiguous to the negative electrode and consists of a hollow cone-shaped mantle of volatilized oxide of titanium rendered incandescent.

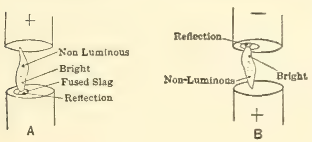


FIG. I

*A*—Metallic arc with negative below.
*B*—Metallic arc with negative above.

Since practically all of the light emitted comes from the arc, it is evident that whether the positive or negative electrode is on top, the light emitted in and near the horizontal direction is practically the same. If, however, the negative electrode is fed from the bottom, the bright portion of the arc is near the lower electrode, casts a large shadow immediately under the lamp, and makes it necessary to reflect the major portion of the light. This arrangement also requires that the long electrode be fed from the bottom, necessitating the use of the long globe and a complicated mechanism.

These disadvantages are not encountered when the negative electrode is fed from the top. This arrangement brings the bright portion of the arc near the upper electrode in such a position that the shadow thrown down is less, and the light reflected from the brilliant surface of the fused pool of slag on the negative electrode is thrown down. Further, it improves the light distribution and makes it unnecessary to use a reflector for purposes other than to entirely eliminate the shadow immediately under the lamp. It is

also a particularly desirable arrangement in that it permits of the use of a small globe, a simple mechanism, which is practically the same as has been in use in standard arc lamps for many years.

Since the electrodes of the metallic flame arc contain the oxides of metals, the vapors deposit as a solid. These vapors, if allowed to touch any part of the lamp, will condense and hang down as a fringe or curtain hiding the light. The success of this lamp depends to a great extent upon the effectiveness with which the fumes are removed. If the negative electrode is fed from the bottom, this soot collects in large masses around the ends of the electrodes, completely obscuring the light. The most effective way to remove them is to cause the electrodes to come together in a violent manner, thus shaking them off. This method has several disadvantages, in that the fumes are only transferred from the electrode tips to the lower part of the globe, where they are still in a position to obscure the light; further, the violent hammer-blow of the electrodes when the lamp feeds, causes the molten slag on the electrode tips to be spattered over the globe. This results in a dirty conditon of the globe after a few hours burning and shortens the life of the electrodes by an amount proportional to the electrode material which is spattered over the globe and wasted.

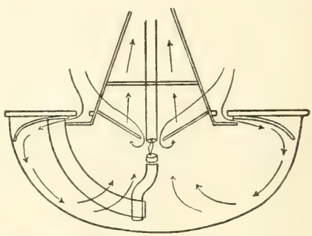

FIG. 2—SHOWING DIRECTION OF AIR CURRENTS

By feeding the negative electrode from the top, the removal of the fumes is very successfully accomplished by directing air currents down around the arc in such a manner that the fumes are caught between the two currents and are carried up the chimney. The air circulation is so arranged that one draught of air constantly brushes the outer reflector and the inner surface of the globe, the other draught of air immediately surrounds the upper electrode, and prevents the arc from running up the side of the electrode and compels it to burn perfectly square. The air is admitted through openings in the lamp case. These openings are so designed that the only effect of the wind is to increase the natural draught in the lamp. The increased draught centres the arc and holds it remarkably steady. This arrangement makes it unnecessary to bring the electrodes together with a violent blow, and effectively removes the

fumes from the lamp, leaving a clean globe and reflector throughout the entire life of the electrode.

The mechanism consists of a pair of feeding magnets for striking the arc, a series cut-out coil for disconnecting the feeding magnets, and a shunt coil for regulating the arc voltage.

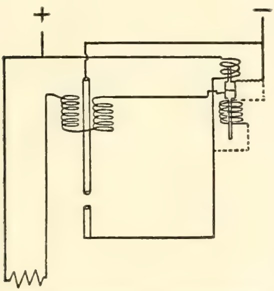


FIG. 3—DIAGRAM OF CONNECTIONS

The metallic flame arc lamp is arranged for operation on direct constant current. This current may be supplied from a constant-current generator, but as will be later described, the use of a mercury vapor rectifier affords an equally satisfactory operation with the many additional advantages peculiar to this class of apparatus. It is operated at 4 amperes with an average drop across the terminals of 68 volts. Since the energy loss in the lamp mechanism is only 8 watts the lamp efficiency is 97 percent.

The light distribution curve of the metallic flame arc adapts it particularly to street lighting. The maximum light intensities of the various arcs used for street illuminations are as follows:

| Type of Lamp | Arc Voltage | Color | Angle Below the Horizontal Degrees |
|---|---|---|---|
| Direct-current Open . . . . . . | 48 | White | 45 |
| Alternating-current Open . . . | 30 | White | 25 |
| Direct-current Enclosed . . . . | 78 | Blue White | 30 |
| Alternating-current Enclosed . . | 72 | Blue White | 15 |
| Metallic Flame . . . . . . . . | 68 | White | 10 |
| Flame Carbon . . . . . . . . | 45 | Yellow | 90 |

A 275-watt flame lamp replaces a standard 6.6 or 7.5 ampere enclosed carbon lamp, and on account of its superior distribution, gives a more uniform street illumination than the carbon arc. If metallic flame lamps were to replace an installation of carbon lamps, it would be possible to increase the distance between lamps ten or fifteen percent and still secure an illumination midway between lamps which is superior to that of the carbon lamps, and at about one-half the energy consumption.

The remarkable light distribution of the metallic flame arc is eclipsed only by the high efficiency of the entire system. In times past, the only source of a constant direct current has been the constant-current generator. The efficiency of such a machine under the best operating conditions is rarely over 80 percent. If the arc machine is operated from the main generating station through an induction motor, the combined efficiency of a motor and arc machine will be approximately 70 percent. If lowering transformers are required for the motor, the combined efficiency will be reduced to approximately 57 percent. The maximum number of arc lamps which can be operated from one arc machine is 120 to 140. The equipment of a large lighting station supplying direct-current lamps will therefore consist of a large number of small machines of very low efficiency.

It has been necessary to operate all direct-current constant-current lamps from a low efficiency arc machine and, regardless of the fact that a direct-current lamp has a superior light efficiency, it has been replaced by the alternating-current series system with its highly efficient constant-current regulator. The advent of the mercury vapor rectifier permits the use of direct-current arc lamps on alternating-current circuits without the use of motor-generator sets. This possibility is particularly valuable, in that it affords an economic solution of the problem of efficiently producing a constant direct current for use with the metallic flame arc lamp.

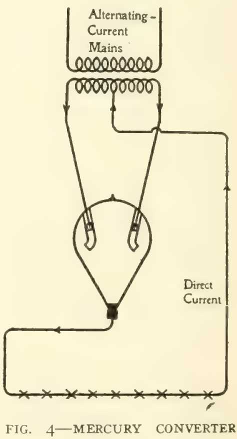


FIG. 4—MERCURY CONVERTER CONNECTIONS

Since the current is rectified before entering the lamp circuit, it is possible to operate direct-current lamps on either 25, 60, or 133 cycles. A complete outfit for supplying direct-current from alternating-current mains consists of a constant-current regulator, rectifier bulb, and a switchboard with the proper instruments, switches, etc. The constant-current regulator is similar in operation to the repulsion automatic regulator used with alternating-current series carbon lamps. A regulator can be wound for direct connection to

any primary voltage up to 13 000 volts.

The current is rectified between the secondary of the regulator and the lamp circuit. In the mercury rectifier, it is necessary to maintain the vapor in a conducting condition, and to reduce the fluctuations of current in the arc to such an extent as will prevent the flickering of the lamps. This is accomplished by so constructing the regulator that it receives sufficient energy from the primary circuit and gives it out again during the period of zero value. In addition, therefore, to performing the function of maintaining a constant current in the circuit, the regulator stores up sufficient energy to maintain a current flow over the zero point of the alternating-current wave. The use of a choke coil or other external inductance in either the positive or negative leads of the rectifier bulb is unnecessary. The rectifier outfit is so constructed that no starting device is necessary. If the primary and secondary switches are closed, the rectifier starts automatically.

The regulator and bulb are enclosed in a boiler iron tank filled with oil. The use of oil affords better insulation, and a lower and more even temperature of the regulator and bulb. The efficiency of this outfit at full load is approximately 90 percent, and the power factor on a 60-cycle circuit approximately 70 percent. The average life of the bulb is 1 500 hours.

If it is desired to furnish an arc circuit for street lighting, to operate from the main generating station, which delivers to the bus-bars alternating current at 60 cycles, the energy consumption of 9.6 ampere direct-current open arcs, 6.6 ampere direct-current enclosed arcs, 7.5 ampere alternating-current enclosed arcs, and 4 ampere direct-current metallic flame arcs, will be as given in the table which follows:—

Assuming that the arc machine for supplying the 9.6 ampere open, and 6.6 ampere enclosed arcs, is driven by an induction motor, the combined efficiency will be approximately 70 percent.

The efficiency of an alternating-current constant-current regulating transformer and mercury rectifier is approximately 90 percent.

The energy required at the lamp terminals for a 9.6 ampere direct-current open, or a 6.6 ampere direct-current enclosed arc equals 480 watts, for a 7.5 ampere alternating-current enclosed arc equals 475 watts and for a 4 ampere direct-current metallic flame arc equals 275 watts.

The energy required per lamp at the alternating-current bus-bars figured at the above efficiencies, neglecting line losses, will be:—

| | | |
|---|---|---|
| 9.6 | ampere direct-current open arc | = 685 watts. |
| 6.6 | ampere direct-current enclosed arc | = 685 watts. |
| 7.5 | ampere alternating-current enclosed arc | = 495 watts. |
| 4. | ampere direct-current metallic flame arc | = 301 watts. |

If the metallic flame arc lamp is compared with the 7.5 ampere alternating-current series enclosed lamp it will be found that the increased cost of the metallic flame electrodes over that of the carbons is off-set by the increased life of the former. The cost of bulb renewals will be approximately balanced by the cost of inner globes, and since the expense for broken outer globes, inspection, etc., is about the same for the two lamps, the maintenance cost of the two systems will be approximately the same.

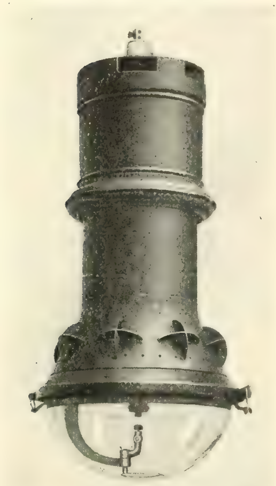

FIG. 5—METALLIC FLAME ARC LAMP COMPLETE

The difference in energy consumption of the two systems represents the saving effected by the use of metallic flame lamps. It is evident that if the cost for generating current is excessively high, the operating costs will be much more favorable to the low energy lamps.

It has been many years since the enclosed type of arc lamp replaced the open type, even though it was done at a sacrifice of light efficiency. Is it any wonder then that all are deeply interested in a metallic flame arc, which not only solves the street lighting problem from a standpoint of economy, and furnishes an equal or superior light to that of the carbon lamp, but insures a commercial application of a direct conversion of electrical energy into light?

# RAILWAY SIGNALING—VIII

## AUTOMATIC BLOCK SIGNALING—ALTERNATING CURRENT

### DOUBLE-RAIL RETURN SYSTEM

J. B. STRUBLE

### DIRECT-CURRENT TRAIN PROPULSION

SIGNALING by the double-rail return system, in which both rails are used as return conductors for the train propulsion current simultaneously with the alternating-current block signaling current, is accomplished by the use of inductive reactance bonds connected across the rail insulations at the ends of the blocks. These bonds offer impedance to the passage of the signaling current, but not to an appreciable extent to the passage of the return train propulsion current. A good form of reactance bond is that shown

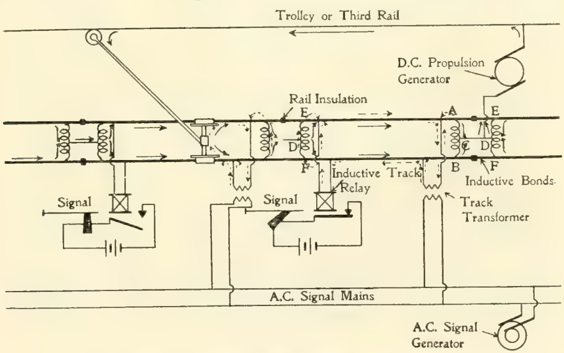


FIG. I—TRACK AND SIGNAL CIRCUITS
The dotted and full line arrows show the direction of the alternating and direct currents respectively.

in Fig. 1, in which the propulsion current passes from the rails into the ends of the coil at *A* and *B* and out at *C*, the middle of the coil of the bond, or in at the middle at *D* and out at the ends *E* and *F*. With equal amounts of return current in each rail the magnetizing effect on the iron is nil, but the signaling current, which flows from end to end of the bond (*A* to *B*), sets up a reactance, which maintains a difference of potential between the rails sufficient to operate the inductive track relay. The propulsion current is shown by full arrows and the signaling current by dotted arrows. Unlike the single-rail return system, the drop of voltage in each rail due to the

propulsion return current is, under favorable conditions, nearly equal, so that little or no propulsion current flows through the track transformer at one end or the track relay at the other end of the block. For this reason it is not necessary to interpose resistances between the track and this apparatus, nor to connect an inductive shunt across the relay coils. The iron of the track transformer has a closed magnetic circuit, that is, it is without an air gap.

Adjustable magnetic leakage filler blocks are inserted between the primary and secondary coils, causing a drop of voltage and limiting the current when the transformer is short-circuited by a train in the block.

FIG. 2—INDUCTIVE BONDS
The wooden covers are removed to show details of bonds.

It is probably never true in practice that equal amounts of propulsion current are carried by each rail of a block owing to unequal resistance due to defective bonding and the like. The difference in the amount of current in the two rails is called unbalancing current because its effect on the iron of the bond is not neutralized by an equal amount of current through the opposite half of the bond.

It should be noted here that a bond as a unit consists of the coil and iron within a cast iron case included between *A* and *B,* and an-

other like bond between $E$ and $F$. The middle points of their coils are connected by a conductor $C\ D$.

Properly the inductive bond around each rail insulation consists of one-half of each bond as $A\ C\ D\ E$ and $B\ C\ D\ E$.

In order to reduce the magnetizing effect of the unbalanced propulsion current on the bond $A\ B$ or $E\ F$ so that its reactance to the alternating signaling current will undergo but little change, an air gap is introduced into the iron of the bond. Obviously, the reluctance of this air gap considerably reduces the reactance to the alternating signaling current, thus requiring additional signaling current through the bond to maintain the necessary difference of alternating-current potential between the rails.

The increased current required by the bond $E\ F$ at the relay end of the block causes additional alternating-current drop in the rails, which in turn necessitates a higher voltage and more current from the track transformer. Thus the bond $A\ B$ at the transformer

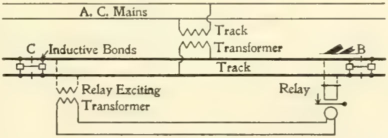


FIG. 3

receives more current than it otherwise requires in order that the bond $E\ F$ at the relay receive enough to maintain sufficient voltage to operate the track relay. Hence the signal mains must have sufficient copper and the generating plants be of sufficient capacity to maintain these conditions.

For the above reasons it is occasionally desirable to locate the track transformer in the middle and use a track relay at each end of the block, or an equivalent, and in some respects better arrangement is to use but one track relay having wire-wound field and armature and energize the field from one end of the track circuit and the armature from the other through a small step-up transformer and line wires. It will be seen that the design of, and power required for, a signal system depends largely upon the kind of maintenance which a railroad company will give the return conductors, the rails, in the way of bonding; for if the bonding is good, with a resulting equal amount of current in each rail, the air gap in the bonds may be made

very small. Such desirable conditions mean a saving in line copper, capacity of generating plant and operating expenses, or if conditions warrant it, a considerable increase in the workable length of track circuit. Ordinarily railroad companies are not willing that even very defective bonding should result in a danger signal with the block unoccupied, so that alternating-current signal plants are now, and more will be, in service in which the inductive bonds have unbalancing capacities equal to perhaps one-half or more of the total propulsion load. The importance of this feature is perhaps more clearly seen when compared with the simplicity and economy of the single-rail system of alternating-current signaling on direct-current roads,

FIG. 4—SIGNALS ON ELECTRIFIED RAILROAD
Inductive bonds are shown on each track between the rails.

and especially on steam roads. In this connection it will be noted that in a general way, the double-rail return system is preferable to the single-rail system in cases where the blocks are long, hence requiring relatively few inductive bonds, and where the running rails are the sole conductors for the return of the propulsion current, whereas the single-rail scheme is to be preferred for the opposite conditions, a notable illustration of which is the Interborough Rapid Transit System in New York City.

The current taken by the track relays and the inductive bonds, has considerable lag owing to the highly inductive nature of the apparatus, while that which leaks from rail to rail, due to the compara-

tively low resistance of the ballast and ties, has a power-factor of unity.

The frequency ordinarily used is 25 cycles. The track relay is of the induction type and does not respond to direct current.

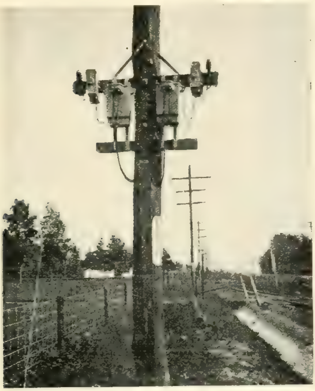

FIG. 5—TRANSFORMERS

Used to step down voltage from high tension signal mains to low voltage signal circuits.

### ALTERNATING-CURRENT PROPULSION

The double-rail return system of alternating-current roads is very similar to that for direct-current roads, except that the inductive bonds have no air gaps and are of smaller capacity, and the track relays are of a somewhat different type.

As the propulsion current has a frequency of 25 cycles or less, the signaling current is given a frequency of 60 cycles in order that a track relay may be used which responds to a current of the latter frequency and not to the former. In other words, the relay operates selectively on frequency and, of course, does not respond to any foreign direct current which may be present.

This system is now in service on the New York, New Haven and Hartford railroad, and gives satisfactory results.

# NOTES ON THE USE OF LOW-PRESSURE STEAM IN CONNECTION WITH ENGINE EXHAUST

J. R. BIBBINS

IN view of the possible development of low-pressure steam turbine work, which seems probable, judging from present indications, a brief discussion of some of the important technical points involved may be of interest. First, consider how much energy is available in steam below atmospheric pressure; second, what percentage of this is transformed into work by the turbine; and third, what percentage by a good steam engine.

The accompanying pressure-volume and pressure-energy curves cover these points; both are based on one pound weight of steam working between 165 pounds absolute pressure and 28 inches vacuum. A theoretical compound indicator card has been sketched in to show, first, how small a part of the total expansion energy of the steam cycle is used in a compound engine running condensing, and second, the relative greater value of high vacuum to the turbine. If properly designed for its work, a turbine is capable of expanding steam right down to condenser pressure, while a steam engine rarely releases below seven pounds absolute.

In the theoretical pressure-volume diagram, the saturation curve has been used, which approximates conditions for the piston engine. But in the energy curve, adiabatic expansion is used to show the theoretical work done in expanding one pound of steam between given pressures, as adiabatic expansion conforms more nearly to the actual conditions in a turbine than the saturation curve. Considering the sub-atmospheric area of the card lying below the saturation curve, the shaded portion represents the work developed by a compound condensing engine, while the solid area represents the additional work developed by the turbine. Thus the relative possibilities of the two types of prime movers may be readily seen at a glance. The other curve shows that the energy of expansion between 165 pounds absolute and 28 inches vacuum is very nearly equally divided above and below the atmospheric line. Accurately speaking, there is available below atmosphere in the adiabatic steam cycle 49 percent of the total energy of the cycle between these particular limits.

Of this 49 percent, the turbine is able to utilize for use-

ful work, practically two-thirds, and the steam engine from one-fifth to one-third. Operating between 15 pounds absolute and 26 inches vacuum, the steam consumption of a well designed steam turbine should be under 35 pounds per brake hp-hr. Now the heat energy released in adiabatic expansion between the above limits, is 113.7 B.t.u. per pound, or $113.7 \times 778 = 88\,500$ foot-pounds as shown by the energy curve, Fig. 1. For a steam consumption of 35 pounds per hp-hr., the steam thus supplies to the turbine 3 097 500 foot-pounds per hour. As one horse-power is equivalent to 1 980 000 foot-pounds per hour ($33\,000 \times 60$) the tur-

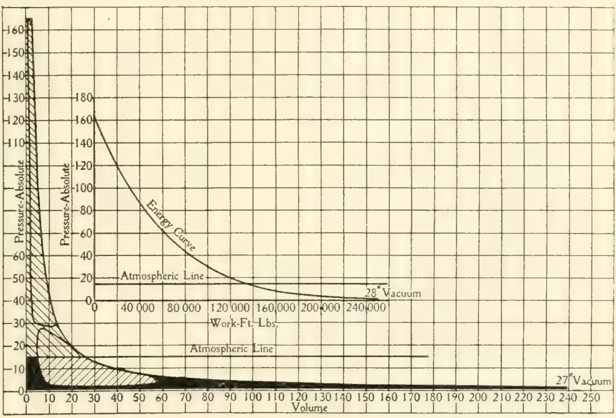


FIG. 1—THEORETICAL INDICATOR CARD SHOWING RELATIVE AREA OF HIGH AND LOW PRESSURE WORKING

Smaller curve shows energy available in adiabatic expansion of steam between given pressures.

bine actually uses 63.9 percent of the available energy in the steam cycle. That these figures are conservative, is shown by the results of a series of tests recently made on the low-pressure section of the low-pressure half of a 1 250 kw, two-cylinder, Westinghouse-Parsons turbine. At full load, this machine showed a steam consumption, working between atmosphere and 28 inches vacuum, of something less than 30 lb. per brake hp-hr.

Considering now the case of a compound reciprocating engine:—If well loaded, release occurs at from six to eight pounds absolute

pressure, even with a high vacuum. This creates a blunt "toe" on the low-pressure card, which is unavoidable, except with a very large low-pressure cylinder. But this increases very materially the friction, bulk and cost of the engine without very much ultimate gain from a practical standpoint. In fact, under a variable load, the triple expansion engine may show no better economy than a compound. But the turbine can utilize low-pressure steam to so much greater advantage that it becomes desirable to run piston engines high pressure with low pressure turbine between engine and condenser. Thus, the turbine acts as the third cylinder in a triple expansion system, but at a much higher efficiency than possible with piston engines. Assuming two 1 250 indicated hp engines with a water rate of 21 pounds per indicated hp-hr., enough steam would be furnished at atmospheric pressure to operate a 1 500 hp low-pressure turbine. This represents an increase in power for the same total steam consumption of 66 percent. If, on the other hand, the non-condensing engines were run condensing, without any change in cylinder ratio, not more than 20 percent increase in power would be realized with 15 percent decrease in water rate. Thus, for the same total steam consumption per hour in the two cases, this method of connecting the low-pressure turbine to non-condensing engine, yields three times more additional power than is obtained by running the same compound engines condensing.

# STUDY MEN*

JOHN F. HAYFORD

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IF you prove to be a successful engineer you will pass through three periods with reference to the acquisition of knowledge and wisdom. First, the school and college period when you acquire through books and teachers. Second, the period comprising the first ten or more years after you leave college, the period during which you will occupy subordinate positions and be in close contact with material facts. By that close contact with facts you will gain experience which will remedy, to a considerable extent, the inevitable defects of any education furnished by books and teachers alone.

Just as rapidly and as certainly as you gain real success by showing ability to make yourself useful in the world, and by using your ability, you will find your responsibilities increased, the demands upon you increased, and will find that you cannot, if you are to accomplish most, remain in direct contact with all the facts of your daily work. You will enter into the third period with respect to the acquisition of knowledge and wisdom. You will find yourself in a position where you must acquire knowledge through your subordinates who are themselves in more direct contact with the facts. The chief engineer of a railroad, the chief engineer of a great government engineering bureau, the head of a great technical school, necessarily sees the facts of the work for which he is responsible mainly through the eyes and brains of his subordinates. In the third, or executive, period then, as in the first, or school period, the successful engineer acquires knowledge and wisdom by utilizing the brains of other men.

When you are in school and college you are, as a rule, learning things which were well known long before your time, you are acquiring knowledge which is well organized by the successive efforts of many men, teachers and authors. Because it is well organized knowledge, already worked over by many men, this concentrated experience comes to you from the past with comparatively little coloring due specifically to the last author and the last teacher in the series through which it passed to you. But it does come to you with high coloring and in a distorted form, because the long series of

*Extracts from an address delivered at Clarkson Memorial School of Technology, Potsdam, N. Y., June, 1907.

authors and teachers have, as a rule, belonged to one profession—teaching—because they have all been thinkers, rather than doers. It is within your power, to a great extent, to remove the inevitable false coloring, and to round out the inevitably distorted form by heeding your own experience to be gained in the second period alread referred to,—the period during which you are to be in engineering in subordinate positions in close contact with facts.

But as you gradually, by being successful, pass into the third period in which you again depend upon utilizing the brains of others, you will find that the facts you must deal with have not been known long, that they are not well organized, that they come to you through one man or through a short series of men only, and that as a rule the relations between the facts are but dimly perceived by the men from whom you get them. Under these conditions the facts and principles come to you highly colored and greatly distorted and but dimly outlined because of the peculiarities of the man, or the few men, through whom you get them. It becomes, therefore, of prime importance to you to understand that man, or those men. To be entirely successful you must study men.

I say, advisedly, that the facts with which you must deal in the third period are of this character. The well known and well organized facts and principles will be dealt with by your subordinates without coming to you for attention.

An engineer does very little directly without the intervention of other men between him and his accomplishment, even when he is in minor, subordinate positions. Even the levelman is dependent on his rodman and recorder. The inspector on construction may see with his own eyes, but he produces changes only by operating through a foreman or perhaps a chain of several men, including the engineer to whom he reports, the contractor, the contractor's foreman, and finally the workmen. The draftsman may seem to be directly in contact with his work, but he really accomplishes something only as he succeeds by means of drawings in guiding the skilled workman whom perhaps he never sees. In each of even these simple cases the effectiveness of the engineer is conditioned in part on his accurate understanding of the thoughts and feelings of the men through whom he works.

As an engineer rises higher in the organization with which he works, his field of influence becomes larger, but the line of men through whom he works to produce material results also lengthens. He works to an increasing degree through other men and it is of in-

creasing importance that he understand other men. Or, if he fails to know men he is apt to fail to rise.

An engineer works through other men not connected with him in any organization by convincing them of the correctness of his view, and of the advisability of doing certain things. He produces results in these cases by convincing. It may seem at first sight that in this respect a man works in a different way through other men according to whether they are his subordinates in a close organization or are outside the organization. But experience will show you that there is no real difference. You can be effective in producing results through your subordinates in an organization only by convincing them that you are right, though it may not be necessary that they understand why your decisions are right. If you do not convince, your subordinates will accomplish whatever is within their native ability to accomplish unguided, but no part of that accomplishment will be due to you.

If you are to succeed,—to be valuable in the world—to know is not enough, you must make others to know. You power of passing knowledge from your own into another man's mind depends largely upon your understanding of that man. Hence you must study him. If you understand him and have a thorough mastery of the topic in hand then your success in convincing him still depends largely on your skill in using language, in making words effective carriers of ideas. Language is one of the tools of an engineer,—a tool which he has frequently neglected because he has as frequently failed to realize that men are also his tools.

As soon as you are well started in studying men you will find yourself studying the need and purpose of organization. For as soon as you fully realize what great differences there are in their principal characteristics, and even how widely the capabilities of a given man may vary at different stages of his life, you will realize why and how it is that a group of men working together as an organization may accomplish much more than the same men could if they worked independently, as individuals.

A very common conception of organization is that it is an arbitrary arrangement by which orders are transmitted by various steps, through different groups of officials, from the man at the head of the organziation to the many men who form the rank and file and do the actual work. Many graduates have shown that they believe that the way for a man in a high position to get a thing done is to order it done. Poor and inefficient administrators may do it that way

The successful administrators are men who act on the principle that their business is to administer unto those below them in the organization in three ways. First, by putting them into such places and under such conditions that they can do their best; second, by giving them orders necessary to show what is expected of them; and, third, by enlisting their wills as well as their bodies and minds in the work of the organization so that they will do their best. The first and third of these, the average graduate has never seriously thought of. He sees in the administrative officer the man who orders. The successful administrator finds his time so thoroughly filled with the first and third kinds of administration, with putting each man in the place and under the conditions most favorable to his effectiveness, and with enlisting in the service the will of the man, that orders fill but a small part of his horizon.

The men near the top in an organization normally do the most difficult work. Normally they are the men who work most intensely and for the longest hours. In the great organization with which I am connected, the civil service of the United States, this is so commonly recognized that it calls forth no comment to see the rank and file leave at four-thirty and come at exactly nine, while others who are in responsible control of the organization work early, late and strenuously.

I have urged you to study men, and especially to study men from a certain point of view,—the point of view of one who wishes to attain success as an engineer. You may properly ask how it is proposed to study this subject. Study it as you should study any other engineering topic. Use the best books you can find, study current practice as shown in current literature, study the facts and principles directly whenever you can

You will find at the outset that no one existing book will serve as a text-book. There certainly are fundamental principles, capable of being put into words, which are daily being applied by successful administrators. But these administrators do not put them into words themselves. They are too busy. Some of them will tell you that they act by intuition. If the principles are put into words it will be done by some one who makes that his chief aim for the time being, some one who will study carefully the words (spoken and written) and the acts of successful administrators, and perhaps failures in that line also. That is the way the excellent text-books on various courses in engineering have been built up, and the transition made from the time, only two generations ago, when Mahan's

Civil Engineering was the single text-book, to the present state of affairs when we have complete and well written text-books in each of many lines of engineering. It was the teacher rather than the successful engineer who put into clear, definite, teachable form the principles used by engineers. So you must not expect the man who is successful in dealing with men, the successful administrator, to tell you how he does it. You must directly, or through others, watch his actions and their effects, listen to his spoken words, and read his writings on all sorts of topics

To sum up: You have in your four-year course been studying material things, the facts of nature and the laws of nature. You have been acquiring that engineering knowledge, knowledge of the forces of nature and the strength and properties of materials, which is absolutely essential to your success as an engineer You have studied man comparatively little. You have acquired your engineering knowledge largely through men and will continue to do so. The soundness of your engineering knowledge depends in part upon your knowledge of men; but what is still more important the effectiveness with which you will use your engineering knowledge depends very intimately upon your knowledge of men. Hence, you are urged, as you do your part in the world, to study men as well as engineering. You are urged to pay attention to all phases of the men around you, to see and appreciate them as literary and artistic men, as well as technical men, as men of feeling as well as men of thought, as incarnated motives as well as thinking and working machines.

To attain to the highest success as an engineer you should not only be able to reach correct conclusions quickly when you have the facts before you for direct observation; you should also have the power to draw correct conclusions quickly from information which comes to you through other men. This power comes largely from knowing men.

To attain to the highest success as an engineer you must not be the type of man who knows how to do things excellently but cannot tell others how to do them,—the man who gets knowledge abundantly but can apply it only through his own fingers. Instead of devoting your energy simply to increasing your own output by fifty or even one hundred percent, it is far better,—you make yourself more useful to the world—by using your energy to increase the output of each of one hundred men by ten percent. The world recognizes this by awarding the prizes to the administrators.

# THE DESIGN AND TESTING OF ELECTRICAL PORCELAIN

DEAN HARVEY

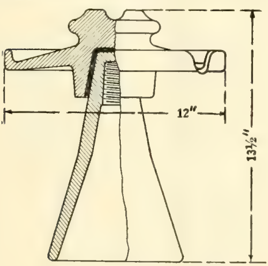
ALTHOUGH high grade porcelain ware, or china, has been manufactured for many centuries, it is only a few years since the use of this material has been extended to the electrical industries. The design of electrical porcelain differs materially from that of ordinary ware on account of the different characteristics desired. High dielectric and great mechanical strength are required, especially in certain types of construction, such as overhead lines, etc. It has been necessary, therefore, to devise new processes to facilitate the manufacture of the new shapes. The methods of manufacture and principles of design are now practically standardized for a large proportion of this material. Careful designing is required to obtain the best results not only to secure porcelain best adopted to the service, but also so that it may be manufactured readily and economically. Quite often a slight change in design will not interfere at all with the design of the apparatus with which the porcelain is to be used, and will render the porcelain much less difficult to manufacture and therefore less expensive.

The price of porcelain necessarily includes both the actual cost of manufacture of the pieces used, and in addition the cost of such pieces as are made up and rejected either on account of mechanical imperfections or failure to withstand electrical tests. The materials used in the manufacture of porcelain are relatively inexpensive as compared with the cost of manufacture, and are not considered in estimating costs. A large insulator is more expensive than a small one, not on account of the larger amount of material used, but because of the greater difficulty in the manufacture. The cost of porcelain is largely dependent upon the number of pieces which can be placed in the kiln at one time, as the cost of firing is practically the same, regardless of the amount of porcelain in the kiln. A metal die is required when "dry pressed" ware is to be made and its cost must also be considered.

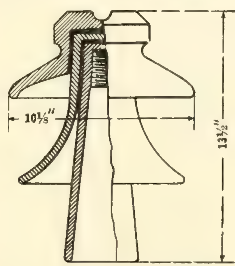
## GLAZES

When glazed porcelain ware is fired, the pieces must be separated so that they will not be held together by the glaze. Unglazed

porcelain is less expensive to manufacture than the glazed material because the extra operation of dipping in the glazing fluid and drying again before firing is avoided, and in addition the pieces may be placed directly in contact with each other, or, if of small size, piled up indiscriminately, thus allowing a much larger number to be fired at the same time. The surface of the porcelain at points of support during firing must be left unglazed so that the ware will not adhere to the seggar, unless it is supported on small pieces of bittstone. This material, however, is not generally used, as it has to be ground off after the firing to produce a smooth surface. Small porcelain bases and similar pieces can usually be fired best when supported on one edge. Standing the ware on edge is also advantageous because more pieces may be placed in the same seggar.




BAY COUNTIES—1900
50 000 VOLT INSULATOR




SHAWINIGAN—1902
50 000 VOLT INSULATOR

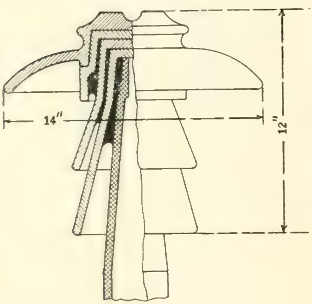
If placed flat they are likely to conform to the surface of the seggar and become warped if that surface does not remain perfectly flat. While the seggars will withstand a higher tempertature than porcelain ware, both of these materials soften somewhat at the high temperatures obtained in kilns during firing and tend to conform to the shape of the supporting surfaces.

The use of a glaze on porcelain insulators is usually desirable, as it provides a smooth, glossy surface which does not accumulate dirt and moisture as readily as the rougher unglazed surface. The glaze also provides a convenient means of coloring insulators so as to correspond more nearly to the color of the apparatus with which it is used. The brown glaze has become practically standard for porcelain insulators used on outdoor overhead lines, because it is less conspicuous than white porcelain, and hence less liable to be used as marks and broken by rifle shots. Experience has shown

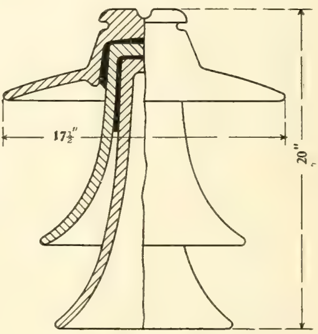
that on two parallel lines equipped with white and brown-glazed insulators, respectively, the breakage was much greater on the line having the white insulators.

PROCESSES

The "dry process" of porcelain manufacture is suitable only for the manufacture of such porcelain pieces as can be formed by means of metal dies, and which are to be used on comparatively low voltages. The clay, which is rather dry when pressed in the die, does not have the compact body obtained by the "wet process," and necessary for high potential porcelain. Dry process porcelain, unless manufactured with the greatest care, is somewhat porous, and hence is liable to absorb moisture. This process is, however,




GUANAJUATO—1905
60 000 VOLT INSULATOR




RIO JANEIRO—1907
88 000 VOLT INSULATOR

suitable for the manufacture of low voltage porcelain, such as bases for fuse blocks, etc., and especially for pieces of irregular shapes, which cannot be turned.

The methods of manufacture of wet process porcelain have been fully described in a former article.* This porcelain is of the quality particularly adapted to high voltages, and may be made in any form that can be turned in a lathe or formed on a potter's wheel by means of a profile tool and plaster mould. The sections of multiple part line insulators are made by this latter process.

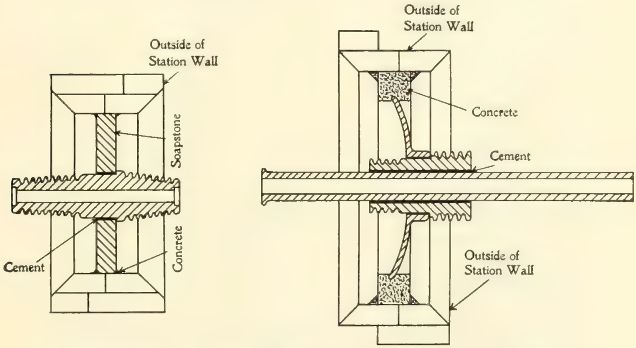
Wet process porcelain costs more to manufacture than the dry pressed ware, when made in quantities, because it is made by hand,

*See *The Electric Journal,* June, 1907, pp. 352-356.

but is less expensive than the latter material when only a few pieces are needed, as it does not require a die.

DIMENSIONS

Porcelain should be as nearly uniform in thickness as possible, as this facilitates uniform drying of the material. Pieces having considerable variation in thickness are very likely to become cracked or warped during the process of drying and firing. It is customary to allow certain variations in the dimensions of porcelain insulators from those specified. A reasonable variation is one and one-half percent either way for dry pressed ware (or three percent total),




PORCELAIN WALL OUTLETS FOR MEDIUM AND HIGH VOLTAGES

and three percent either way for wet process porcelain (or six percent total), this larger variation being allowed because the ware is made by hand. Greater accuracy may be obtained, but in that case the cost will be higher on account of the larger proportion of pieces rejected.

LIMITING VOLTAGES

Porcelain of the best quality is of very high dielectric strength. As the thickness is increased, however, it becomes much more difficult to obtain well vitrified ware without small cracks or other flaws in the interior. This fact practically limits the voltage which a single piece of porcelain can withstand, and it is therefore customary to use multiple-part insulators for the higher voltages. In general, insulators should be designed so that no single piece will be tested at more than 80 000 volts, and a somewhat lower test is desirable.

There is a common impression that breakdown over a high tension insulator is due to surface leakage. Unless the surfaces are wet or are covered with some conducting material, there is no appreciable leakage of current, as the only current flowing is the charging current of the insulator considered as a condenser, which is of small amount. The principal cause of the breakdown seems to be the rupture of the film of air immediately adjacent to the insulator, on account of excessive electro-static strain. The dielectric between a circuit and ground consists not only of the porcelain insulator, but

NEW INSULATOR FOR EXTRA HIGH VOLTAGE SERVICE

METHOD OF SUPPORTING INSULATOR FOR EXTRA HIGH VOLTAGE*

also of the air adjacent to it. When a dielectric is composed of several materials in series, that material having the lowest dielectric strength will be the first to break down, other things being equal. It is a well known fact that air has a much lower dielectric strength than either glass or porcelain. When a gradually increasing voltage is applied to a porcelain line insulator with a metal pin, the only current that passes at first is the very small charging current of the insulator. When a certain voltage is reached, the electro-static field

*Other types of suspended insulators are described in papers before the American Institute of Electrical Engineers, June, 1907, by E. M. Hewlett and H. W. Buck.

attains such a strength that the air near the two terminals or electrodes is ruptured, causing a brush discharge, and the ruptured air becomes a semi-conductor serving to extend the electrodes, and therefore increase the current. This rupturing of the film of air and consequent increase in the electrodes and in the brush discharge, tends to continue indefinitely, but is retarded by the cooling effect of the porcelain, its shape, etc. A slight increase in the voltage, however, will considerably extend the area of the brush discharge. The thickness of the dielectric at the top of many line insulators is small, causing a strong electro-static field at that point, which tends to rupture the air. The shape of the insulator has much to do with this action, as, by proper design, the surface of the porcelain may be brought out into an electro-static field so weak that the air adjacent to the porcelain cannot break down under its influence.*

### LINE INSULATORS

Insulators for outdoor service, in addition to meeting the requirements for interior work, should be so designed that they will withstand the most extreme weather conditions of the locality in which they are to be used. Climatic conditions vary so much in different sections of the country that an insulator which proved entirely satisfactory in one locality might be inadequate for similar service in another territory. For instance, the conditions near the sea coast with its salt fog are much more severe than in dry mountainous regions. Insulators are also subjected to very severe conditions in certain localities on account of excessive condensation of moisture due to sudden and extreme changes in temperature. A striking illustration of the effect of sudden variation in temperature on insulators has occurred on several lines, where parts of glass insulators have cracked off owing to the sudden warmth on one side of the insulators at sunrise. On account of these variations in service conditions, definite information regarding the size of line insulators required for a certain voltage cannot be given; but the necessary dimensions of the insulator can best be obtained by a study of the various forms which have operated successfully under similar conditions.

With the increase in voltage of high-tension transmission lines has come the demand for larger and stronger insulators. Insulators of large size are made in several parts, held together either by ce-

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*For more extended information on this subject see "The Construction and installation of High Potential Lines," by Mr. M. H. Gerry, p. 364-388, *Trans. International Electrical Congress,* St. Louis, 1904.

ment or glazed together while being fired. Neat Portland cement or litharge and glycerine are commonly used for cementing the parts together. For the higher voltages, steel towers have been used instead of wooden poles, with long spans between towers, thus reducing the number of insulators necessary, but requiring both insulators and pins of great mechanical strength. The limiting size for this style of insulator and pin has practically been reached, and for voltages higher than 90 000 volts, a new form of support for line wires is needed. Experimental work has been carried on with several types of suspended insulators, in which insulating discs of various shapes have been strung together in series to support the line. One high potential line is now being equipped with this type of insulator, but the new construction is still in the development stage, and experience only can determine whether or not it is best adapted for the service conditions.

### PORCELAIN VS GLASS INSULATORS

Glass insulators have been used to quite an extent on circuits of less than 25 000 volts. They have the advantage of low cost and cheap inspection. Defects in the material which would interfere with its dielectric strength may be found by inspection, thus rendering electrical tests unnecessary. Glass, however, is open to the serious objection that material which has not been properly annealed is likely to have stresses set up within it which will cause it to break when exposed to comparatively slight changes of temperature. Porcelain is somewhat more expensive than glass, but has greater mechanical strength and is less brittle. Very careful tests for dielectric strength are required in order to determine the quality of porcelain insulators, as defective material ordinarily cannot be detected by examination.

### WOODEN VS METAL PINS FOR LINE INSULATORS

Electrical engineers have been divided in opinion as to the relative merits of wooden and metal pins for porcelain line insulators. The wooden pin has an advantage in that it provides a certain amount of insulation, and the electro-static field with the resultant brush discharge is much less pronounced than with a metal pin. But the wooden pin is subject to injury by brush discharge at the pin, and when this occurs or an insulator breaks down the pin is usually destroyed, thus allowing the line to fall and frequently burning a cross-arm. The metal pin has the advantage of greater mechanical strength and holds the insulator and line in position even though the insulator may have broken down electrically. The metal pin

is considered preferable for use with insulators which have ample margin of safety for the service conditions. When this margin of safety cannot be obtained by the insulator alone, a wooden pin is advisable in order to obtain the necessary insulation. However, with long spans, especially at high voltages, metal pins are necessary in order to obtain the required mechanical strength.

### ELECTRICAL TESTS

In general, the conditions under which tests are made should correspond as nearly as possible to the conditions of service. It is

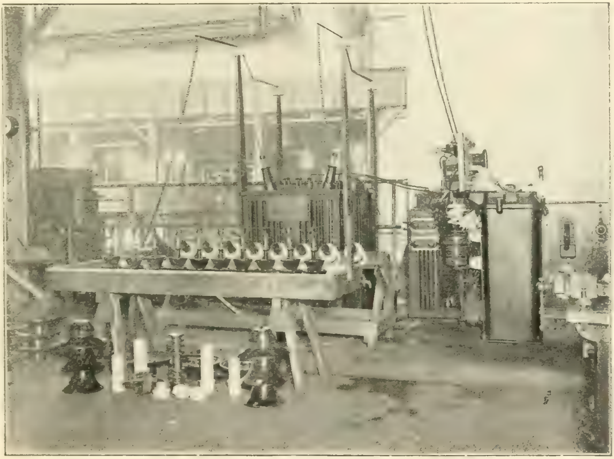


FIG. 1—GENERAL VIEW OF AN INSULATOR TESTING DEPARTMENT
Showing transformer, controlling apparatus, insulators in water trough and bushings fitted with jigs on testing rack, also some of the types of insulators tested.

customary to test porcelain parts at a somewhat higher voltage than they will be subjected to during the tests upon the finished apparatus in which they are used, in order to allow for slight variations in the voltage of the testing circuit and prevent the breakdown of the porcelain after assembly. Practice has clearly established the fact that a time test is necessary in order to detect defects, as insulators which withstand a certain test voltage momentarily will not necessarily withstand it continuously, or even for a short time. The usual time for a high voltage test is one minute.

In order to detect the point at which the breakdown of an in-

sulator occurs, it is sometimes desirable to apply the testing voltage for a sufficient length of time to burn a larger hole at the point of puncture. One of the most convenient methods for accomplishing this result is to place a resistance or reactance in parallel with the circuit breaker in the primary circuit of the testing transformer. When the overload caused by the breakdown of the insulator opens the circuit breaker the reactance is automatically thrown in series with the transformer and cuts down the current. The reactance may be proportioned so as to allow only full-load current in the

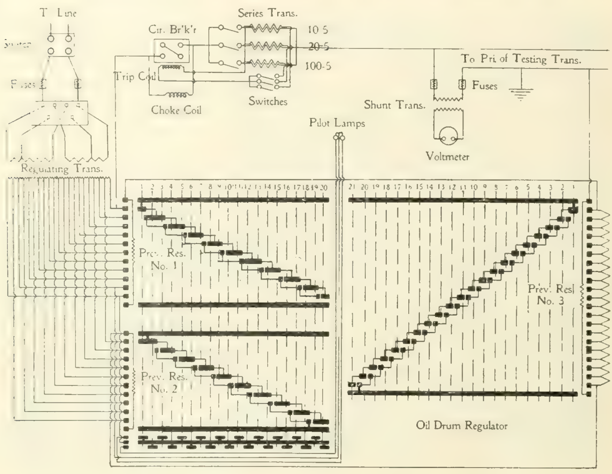



FIG. 2—DIAGRAM OF CONNECTIONS FOR TESTING ARRANGEMENT SHOWN IN FIG. 1

transformer, so that the burning of the insulator may be continued without injury to the transformer.

Fig. 1 shows a testing outfit for testing porcelain insulators, and Fig. 2 gives the diagram of connections. Variations in voltage are obtained by varying the primary voltage of the testing transformer by means of a regulating transformer, auto-transformer and oil drum regulator. Two regulator drums are used in order to provide for small variations in the test voltage. The two pilot lamps indicate the direction in which to turn the auxiliary drum. In order to raise the voltage by five percent steps, the main drum is operated. To raise the voltage by one-fourth percent steps the auxiliary drum

is moved clockwise if the right hand pilot lamp is lighted, or counter-clockwise if the left hand pilot lamp is lighted. When the auxiliary drum is moved until against the stop, the main drum is to be moved one notch and then the auxiliary drum moved in the opposite direction. A choke coil is connected in parallel with the oil circuit breaker to allow punctures in insulators to be located as described above. A number of series transformers with different ratios are used in connection with a tripping coil to give the circuit breaker a wide range. Testing racks, a variety of suitable jigs, and

FIG. 3—TESTING DEPARTMENT OF A LARGE PORCELAIN MANUFACTURING ESTABLISHMENT

other fittings facilitate the quick handling and testing of a number of insulators at the same time.

One of the most convenient methods of testing porcelain line insulators and similar material is to place the insulators in a water trough so that the water forms one terminal of the insulator. Porcelain line insulators are tested in this manner, the insulators being inverted, with the head immersed in water so as to cover the side wire groove, and with the hole for the pin filled with water to serve as the other terminal. The testing department of a large porcelain factory is shown in Fig. 3. The porcelain pieces under test are large multiple-part line insulators. Each part is tested separately before assembly, and the complete insulators are also tested.

# SALES CONTRACTS—III (Concl.)

B. A. BRENNAN

### DAMAGES IN GENERAL

The measure of damages recoverable for breach of warranty in quality is, in general, the difference in value between the article actually furnished and that which should have been furnished, together with such reasonable expense as the buyer has incurred in consequence of the breach.

The buyer may, however, by failing to inform the seller within a reasonable time after discovering the defect, thereby depriving the seller of his reasonable rights, lose his remedy.

Where goods are sold for a particular purpose there is an implied warranty that the article is reasonably fit for the purpose.

Goods sold by description in the absence of any express stipulations as to quality, implies a condition that the seller shall supply such goods as are commercially known under the description and of merchantable quality. Goods sold by sample must correspond in quality with the sample.

The seller who makes no warranty as to the thing sold cannot be held answerable for latent defects of which he had no knowledge. But if he sells it for a particular purpose, the buyer making known to him at the time for what he buys it, the seller thereby warrants it fit for such purpose, and free from latent defect. But the manufacturer is only liable for failing to exercise the proper degree of care or skill in the selection of the material and the manufacture of same, and he impliedly warrants that he has done so.

The manufacturer who makes and sells machinery for special use warrants that it is free from latent defects which render it unfit for the use to which it is to be applied, but (in the absence of an express contract,) he does not warrant that it is perfect or the best for that purpose, but, only, that it is reasonably fit and proper for the use designed. If one orders a casting, which cannot be made without blow-holes, there is no warranty implied that he will receive one without blow-holes, but there is a warranty that there will not be any more or larger blow-holes than is usual in the process of manufacture designed to make such articles fit and proper for use.

The seller of a harvesting machine guaranteed to supply any parts proving defective in construction. The machine broke down during the harvesting season when help had been collected and no

other machine could be obtained. The ripened grain was consequently injured, and a loss in wages ensued, but it was decided that the grain could not be recovered for, and that the recovery was limited to the actual expense of repairing the machine.

The implied warranty of the article does not extend beyond the article itself to other articles or appliances connected therewith, even though included in the same order and purchased at the same time.

Latent defects unknown to the seller in a specific thing sold will not render him liable unless there is clear evidence of implied warranty on his part. Express warranties are often given in writing to cover defects not readily discernible, and under them the buyer may seek remedy to the extent of the warranty, but the terms of the warranty limit the liability of the seller. In machinery contracts the warranty against defective material usually extends to a period of one year; the seller to furnish new parts to replace those found defective within that time, but no action can be maintained upon the warranty without notice of breakage and without the seller's neglect to furnish the defective parts.

*Unreasonable Delay in Delivery*—Where there is unreasonable delay in delivery, the customer has the same remedies as recited in the preceding paragraph; namely, whether to refuse the goods, or to receive them and claim damage for the delay. If damages for the delay, he must make his method of receiving possession such as to show the seller that he does not waive his right, as if he receives the goods without making objection, it is (prima facie) a waiver on his part to claim damages, but to the contrary when the goods are received with an explicit statement that such damages will be claimed.

Generally it is presumed that the purchaser should so far rely upon the seller's punctual performance of the contract as to be fully justified in making the necessary preparations to receive the property contracted for, and that he should be compensated for failure of the seller to deliver; that is if the damage can be shown with certainty, and not speculative nor conjectural. The broad general rule is that the party injured is entitled to receive all his damages, including gains prevented as well as losses sustained. But this rule is subject to two conditions:—

1st—The damages must be such as may be fairly supposed to have entered into the contemplation of the parties when they made the contract, such as may naturally be expected to follow its violation:

2nd—They must be certain, both in their nature and in respect

to the cause from which they proceed. These two conditions, however, are independent and quite separate; the damage claimed may be the natural, ordinary and necessary result of the breach, and yet, if uncertain, would be rejected, and while they may be both certain and definite, yet, if they were such as would not naturally follow from such a breach, but from special circumstance collateral to the agreement itself, or extraneous to the object of the contract, they would also be rejected.

*Remedies in General*—The question as to the remedies to the buyer is, however, often influenced and governed by the special nature of the contract, and the damage to the customer may also include such matters as both parties in making the contract might reasonably expect to be the consequences in the particular case and in regard to which they must be taken as having been intended in the contract. Anticipated profits may have been in contemplation; not speculative or conjectural, but capable of being ascertained with a reasonable degree of certainty. By the special circumstances of the contract, special losses might accrue, and these might be known to the seller at the time the contract was entered into.

In contracts which contain the often called "Penalty" and "Liquidated Damages" clauses, (reference to this subject is made later), when the promise was the payment of a certain sum of money, nothing more than this sum, excepting, possibly, the interest, can be recovered. But when the contract does not contain such stipulation, damages may be recovered to such extent as can be measured, usually by an application of the following rules which have been laid down in the United States Court:—

1st—"Such as may fairly and reasonably be considered as arising naturally; that is, according to the usual course of things from such breach of the contract itself".

2nd—"Such as may reasonably be supposed to have been in the contemplation of both parties at the time they made the contract, as the probable result of the breach of it".

3rd—"Such as arising out of the special circumstances under which the contract was made where such circumstances were communicated by the customer to the seller".

4th—"But if such special circumstances were wholly unknown to the party breaking the contract, he, at the most, can only be supposed to have had in his contemplation the amount of injury which would generally rise not affected by any special circumstances".

The customer can never recover more than the actual loss he

has sustained, and loss, in that sense, does not contemplate recovery for great disappointment, hurt feelings, or vexation of mind; and the party who is injured is also required to render the damages as light as possible. If he, indifferently or carelessly, allows the damages to become unreasonably large, the increase will fall upon himself.

### LIQUIDATED DAMAGES AND PENALTIES

Liquidated Damages and Penalties are often too confused, and the layman usually construes them as meaning practically the same thing.

*Liquidated Damages*—It is legal for the parties to contract, and it is not infrequently done in sales contracts, to agree that if the seller commits a breach of the agreement by failing to ship or erect the apparatus complete within a specified time that the customer will suffer damage thereby, and to assess in the contract those damages at specific rates, and which the seller is to pay to the customer in the event of such default. The amounts so paid are termed "Liquidated Damages".

*Penalties*—Penalties are sums fixed by the parties to be paid to one or the other for failure to perform by one or the other, not intending that the amount to be paid shall cover the damages which would be sustained, but more in the attempt to insure performance. In such cases, if the issue be tried, the amount to be paid is usually limited to the amount of actual damages, regardless of the sum specified in the contract. The courts have adopted the following rules of construction in contracts of this kind:—

1st—"If the contract is for a matter of certain value, and a sum is fixed to be paid on breach of it, which is in excess of that value, then the sum fixed is a 'Penalty' and not 'Liquidated Damages'."

2nd—"If a contract is for a matter of uncertain value, and a sum is fixed to be paid on breach of it, the sum recoverable is 'Liquidated Damages'. There is nothing illegal or unreasonable in the parties by their mutual agreement settling the amount of their damages, uncertain of their value, at any sum on which they may mutually agree".

3rd—"When a contract involves several distinct matters of various kinds, and one fixed sum is stipulated to be paid for a breach of whatever kind, it is a 'Penalty', not 'Liquidated Damages'."

Contracts of this kind are always construed in accordance with

the intention of the parties to it, and regardless of the particular terms used. If the spirit of the contract shows that a penalty was intended the recovery will be limited to the actual damages, notwithstanding that the words "Liquidated Damages" may be used in the contract. Again, where the word "Penalty" may be implied, if the contract indicates that "Liquidated Damages" were intended, the amount may be recoverable in full.

A clause considered binding, covering Liquidated Damages, is as follows:—

"For each day of delay beyond the time set in the contract for completing the entire work herein specified, the customer may withold from the seller's total compensation the sum of ...... Dollars, ($......) : not as a penalty, but as liquidated damages fixed and agreed to in advance by the parties hereto, and as a proper compensation to the customer for the loss caused him by such delay."

ASSIGNMENTS

*Assignment of Contracts*—An assignment, as applied to contracts and distinguished from negotiable instruments, is a transfer by one person to another of property, or interest in property, whether in possession or in action, or whether real or personal.

No one can be compelled to accept the performance of a contract from one who is not a party to it; nor can a liability under a contract be assigned to another without the consent of all parties. Contracts are frequently discharged by a change in the parties thereto, by a new party being substituted for the previous one, and by agreement of all the parties; although the terms remain the same.

Although by ancient rules of common law all assignments of rights which a person possessed under a contract were forbidden, on the ground that it encouraged maintenance and litigation, the same doctrine exists now, but only nominally, as usage and custom have practically deprived it of all force, and to meet the demands of commercial and industrial life the courts accept the rule of protecting assignments of rights, under certain forms of procedure. In some states an assignee may sue in his own name, but in the absence of such statute he sues in the name of the assignor to his own use.

A contract for personal services cannot be assigned, although future wages to be earned under a contract for employment actually existing may be, even though it be indefinite as to time or amount.

An assignment of a debt carries with it all collateral securities which the creditor may hold for its enforcement, and all remedies which the assignor had, and the assignment binds the debtor without any assent, or even with dissent, on his part.

No particular form of assignment is necessary, and any order, writing, or act, whose intent is to make an assignment of a particular right or debt is recognized as valid. Although effectual as between the assignor and assignee from the time made, it does not bind the person liable until he has received notice of it; and until he is notified of it he is protected in any debt he may pay to his original creditor. The assignor impliedly warrants good title to the thing assigned, but can relieve himself from liability of it by stipulation in the assignment.

There is no implied warranty on the part of the assignor that the obligor will pay the debt, or that he will repay the assignee the consideration in case the obligee fails.

The Supreme Court has ruled that where two or more assignments of the same debt have been made to different assignees at different times, the assignee who first gives notice to the debtor obtains priority, even though this assignment may be of a date subsequent to the other.

An equitable assignment of a debt as against third parties must, however, have consideration to support it, although without it the debtor cannot question the assignment.

### STATUTES OF LIMITATION

All states have what are called "Statutes of Limitation". They provide the periods of time within which actions for debt, breaches of contract, or other claims must be brought. The periods vary in many states, ranging from one year to twenty years, depending on the nature of the action. Generally, actions or judgments on contracts under seal are longer than simple contracts. The policy of such statutes is to encourage promptness in the prosecution of remedies, and they prescribe what is supposed to be a reasonable period for the purpose. They are founded on the general experience of mankind, that valid claims are not usually allowed to remain neglected, and the lapse of years, without any attempt to enforce demand, creates a presumption against original validity, or that it has ceased to exist. A claim is outlawed and becomes unenforcible by reason of lapse of the period fixed by the statutes of limitation for bringing action; they beginning to run from the due date of the claim. Said statutes, however, provide that a claim may be revived after it has become barred or outlawed by a new promise to pay the debt, by a subsequent acknowledgement of the debt, or by a part payment on the debt.

# METERING COMMERCIAL ELECTRICAL CURRENTS

## INTEGRATING WATTMETERS

From an article by H. MILLER,
Assist. Superintendent, Newark Works, Westinghouse Electric & Mfg. Company

INDICATING or deflecting forms of ampere, volt and wattmeters record the amount of power passing through a circuit, by means of the movement of one element of the instrument against an opposing force. The extent of such motion as shown by an index moving over a graduated scale, is an instantaneous indication of the value of the power flowing.

To obtain a cumulative record of the power used during an interval of time, as when metering currents in commercial circuits, it is necessary that the element of time be taken into account. This is done by arranging an instrument so that one of its elements is moved a definite amount in a given time for each unit of energy passing through the circuit. By a suitable mechanism this movement is permanently recorded or registered in terms of the standard unit, the kilowatt-hour. To the concentration of these features into a commercial form of instrument, the term "integrating" (make entire) wattmeter is applied.

The various classes of electrical energy to be measured commercially resolve themselves into direct and alternating current, the former by two or three-wire systems of distribution, the latter by single or polyphase systems.

Alternating current, whether inductive or non-inductive has been registered through types of meters with commutators, but these have in most instances given way to the induction types owing to the several advantages the latter have over the former. The induction integrating meter is either a "current" meter or a wattmeter (a well known type of "current" meter was the Shallenberger ampere-hour meter).

A description of a wattmeter built on the induction principle, which has been recently developed, will no doubt prove of interest.

As actually worked out, there is an electro-magnet as shown in Figs. 1 and 2, where *A* is the voltage (potential-shunt) coil, it being connected across the circuit, while *A'* consists of a core of laminated iron surrounding the former, the two elements in combination forming what is termed the shunt field. Two series coils (one pair) shown at *B* are in series with the two-wire circuit (*B* for a

three-wire circuit would consist of four coils, two pairs), while $B'$ is also a core of laminated iron, partly surrounding the former, these two elements forming the series field. At $C$, midway between $A$-$A'$ and $B$-$B'$, is a disc (armature) upon which a torque is exerted, the disc being the primary movable member of the meter. At $D$ placed somewhat to the right of the axis of $C$ is a permanent magnet, it being placed with reference to $C$ so that the disc is midway between the poles, the effect of such a combination resulting in what is termed a magnetic brake.

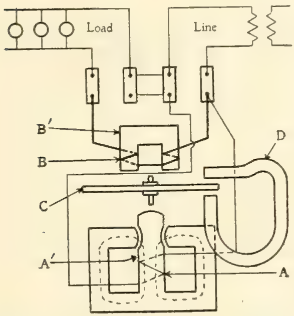



FIG. 1—INDUCTION TYPE WATTMETER
Diagram of connections.

The induction principle is involved in the above construction since the element $C$, Figs. 1 and 2, known as the closed secondary (revolving disc) has induced in it eddy currents through the magnetization set up by the shunt and series fields. The shunt field is so designed that its magnetic field is displaced 90 degrees in phase from the series field, the resultant magnetizations thus creating a rotating field.

The induced currents in the revolving secondary (disc) create a field which lags behind the resultant field set up by the shunt and series fields, thereby creating a torque on the secondary, and hence rotation of the disc, such rotation being proportional to the energy passing.

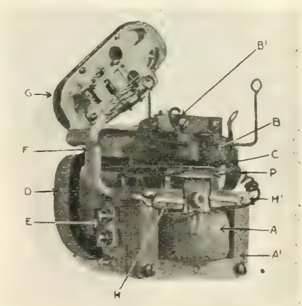



FIG. 2—INDUCTION TYPE WATTMETER

Rear view, the recording mechanism being tilted to show details and method of detaching.

The permanent or brake magnets $D$, Figs. 2 and 3, act as a retarding force, which force varies directly in proportion to the rate of rotation. The speed of the disc is therefore always proportional to the energy passing. The spindle supporting the disc has at its

upper end a small transmission pinion, so that the rotation of the disc is transmitted to the permanent recording mechanism. The latter is shown tilted to one side for convenience of description in Fig. 2. Integrating induction wattmeters have an accuracy equivalent to that found in the best indicating instruments, and with a range of registration many times greater. The best types of meters are calibrated with the greatest accuracy before leaving the manufacturer's testing rooms and improvements in design now in use make it possible to preserve this accuracy during a long period of commercial use. Permanency of calibration in a meter is determined by the degree of refinement entering into the design and construction of bearings, electro or work-magnet, permanent magnets and moving elements.

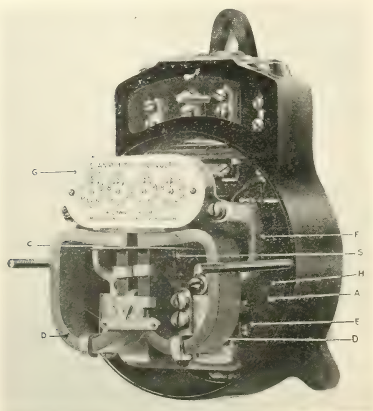


FIG. 3—INDUCTION WATTMETER
Front view, showing arrangement of parts.

### BEARINGS

Bearings are of vital importance. Because of the wear produced, the amount of friction in the bearings constantly increases with service. It is of great importance, therefore, to thoroughly understand the features of design which produce the wear, as this naturally indicates the means to minimize the trouble. It is impossible to entirely eliminate friction or to prevent its gradual increase in a meter in service. Attention has, therefore, been directed towards the incorporation of features in the moving element and in the bearings, which make this wear very slight, since friction then has a value as nearly constant as possible.

In a well designed meter the principal friction occurs between the moving element and its support and its amount is ordinarily governed by the kind and quality of material of which the bearings

are made, the condition of their surfaces and the force with which the surfaces are pressed together.

Changes of calibration which occur in meters during service are due either to wear arising from the weight of the moving element, or to an accidental injury. The greater the pressure caused by the weight of the moving element, the more rapid will be the wear of the engaging surfaces, the more serious the injury occasioned by an accidental blow or jar and the less certain the permanency of calibration, however well a meter may otherwise be designed.

Fig. 4 illustrates a modern design of bearing. At the base of the main staff, in an inverted position, is a cupped sapphire jewel mounted in a removable sleeve. A corresponding jewel is placed in the end of the adjusting screw, which forms the lower half of the bearing. In the space between the two jewels is a hardened steel ball whose polished surface is slightly less in radius than the jeweled cups, thus reducing the friction to an inappreciable amount owing to the smallness of the points of contact. Moreover, as friction is divided between the upper and lower surfaces of the ball, the amount of the wear upon the jewels is again divided, while the wear upon the ball is evenly distributed over its entire surface as it presents constantly changing points of contact to the engaging jewels. As the disc rotates, the ball moves with a rolling motion in the cup.

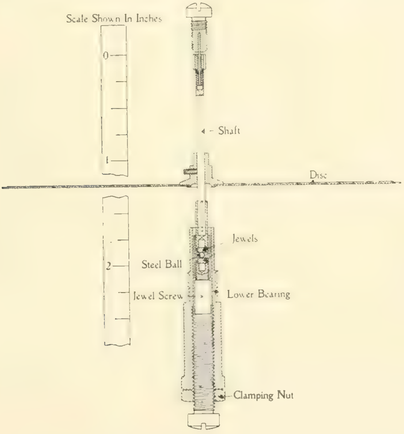


FIG. 4—DETAILS OF BEARING AND CORRUGATED DISC

Theoretically, one is led to believe that a rubbing contact would more correctly define the working condition of this bearing, but to bear out the theory that a rolling motion does exist it is only necessary to consider the effect of magnetic balance of the disc, also the

slight vibration of the disc through the action of the alternating magnetic field.

### TORQUE, WEIGHT AND FRICTION

Torque or turning moment in a meter is the impelling force—the force doing work—and is proportional to the load. Theoretically, torque should do no other work in the meter than that imposed by the Foucault currents induced in the disc by the permanent magnets; actually, however, there is another element of work to be considered, viz., friction. To make the effect of friction as slight as possible, the ratio between friction and turning moment should be very large, as this ratio is a determining factor in the permanency of calibration. In practice this ratio can never be made so large that the friction effect is negligible, but it can be reduced to a constant co-efficient by proper design and construction.

The weight of the moving element determines the meter friction and commands serious attention. Upon it depends not only the initial amount of friction, but also the rate at which this friction will increase with wear. Lightness of the moving element is of too great importance in establishing permanency to be sacrificed for the sole purpose of gaining torque for it is not the increase of torque but a maximum value of the ratio of torque to weight that is desired, and adding to the weight alone does not increase this ratio. It does, however, introduce a positive danger in that it increases wear of pivots, thereby decreasing permanency of calibration and increases the danger of accidental injury. In the endeavor to obtain maximum ratio between torque and weight, it is evidently a distinct advantage to reduce the weight as much as possible. Unfortunately, however, there is a certain minimum, fixed by the amount of material necessary for mechanical strength, below which the weight cannot be reduced. In determinating this amount, skillful designing is needed, that the several factors which establish the torque may be adjusted to give the greatest value of torque for a given safe weight, and at the same time, to give maximum total torque in order to obtain the highest ratio between the turning moment on the disc and the friction.

While friction is proportional to the weight of the moving element, it is a constant quantity at all speeds and causes a fixed retardation at all loads. Its effect, therefore, on the accuracy of the meter is to make it record too slowly and show a large percentage of inaccuracy on light loads. Thus, if the pivot friction amounts to

one-fourth of one percent of the full-load torque, a load of one-fourth percent will just start the meter; at one-half of one percent load the meter will run fifty percent slow; at one percent twenty-five percent slow, and at ten percent about two and one-half percent slow, the error decreasing as the load increases, until its effect at larger loads is almost eliminated. Assuming, however, that the torque at full-load is doubled while the friction values remain the same; the result will be that the friction will have but half the effect upon the speed of the meter, and its accuracy will be correspondingly increased.

The claim that a meter having high torque is superior to one having low torque is thus seen to be true only when the high torque is obtained by means of high efficiency in the work magnet which drives the moving element.

From these considerations it will be seen that in determining the relative merits and possibilities of different designs, it is very desirable to have a clear understanding of the relations which these elements have one to another. The performance and permanency of meters of similar design and of equal accuracy when new can be very closely predetermined by comparing their torque per unit weight of moving element, and bearing in mind that, even though they should happen to have equal torque ratios, the meter with the lighter movement is very much to be preferred.

The moving element shown in Fig. 4 has a disc of aluminum which is corrugated in such manner that it is stiffer and stronger than a plain disc of twice the thickness. Such a light moving element has low static friction which enables it to move quickly and respond accurately to load fluctuations.

### COUNTER-FRICTIONAL TORQUE

In order to overcome the initial friction, it is necessary to provide an additional torque. This is effective in eliminating the errors due to initial friction because of the fact, noted above, that friction is independent of speed and load.

To accomplish this, an auxiliary field independent of the series field is provided consisting of two adjustable short-circuited coils carried on small studs and so placed that their axis of rotation is coincident with the shunt air gaps through an angle of approximately 25 degrees. The torque created by these compensating windings, being independent of the series field, allows of an accurate adjustment of the counter-frictional torque to just the value which will

overcome friction. The meter is thus in a state of balance and the least current flowing through the series coils as a result of load on the line will cause a movement of the disc and will be accurately measured and recorded.

In Fig. 2 are shown the two adjustable compensating windings in the form of short-circuited copper loops *H-H*. Varying the position of *H* in the air gap varies the compensating effect, thus causing the disc to revolve either faster or slower as may be required. The arrangement is such that these parts are easily accessible when the cover of the meter is removed.

## REGULATION

As important as the element which creates the torque, is the regulation which must be applied. In the early days this was accomplished in several ways, such as by the use of fans, while now in the latest type of meters, the magnetic brake is applied.

*Permanent Magnets*—A controlling force varying directly with the speed is obtained by causing the aluminum disc to pass between the poles of two permanent magnets whose fields induce eddy currents in the disc. The interaction between the fields of these eddy currents and the fields of the permanent magnets produces a "retarding" torque that is proportional to the energy passing through the operating coils, i. e., to the driving torque.

In the production of a permanent magnet for use in meter work a very hard steel of predetermined alloy is required. It must be correctly forged, highly tempered and properly magnetized. A small air gap is necessary, and in mounting and adjusting the magnets they are securely locked as shown at *E*, Figs. 2 and 3.

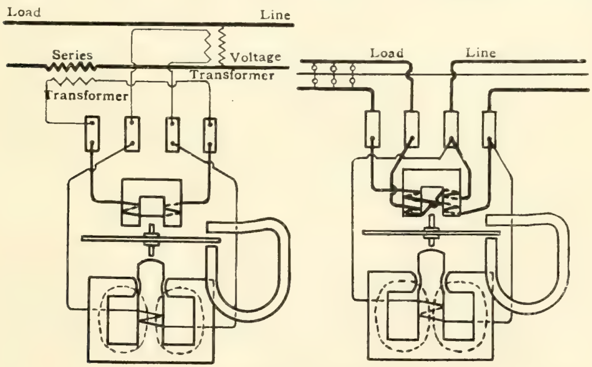
*Aging*—Ordinarily, permanent magnets will, in time, show a gradual diminution in strength, a property known as "aging." The seriousness of this in its bearing on permanency of calibration is quite evident and has led to the development of a routine of treating processes by which a magnet of good quality may be artificially aged, thereby greatly increasing its permanency at a slight sacrifice in strength.

*Speed Adjustment*—The speed of the disc is controlled by the permanent magnets. Moving the magnets in from the edge of the disc will increase the speed and moving them outward will reduce the speed at any given load. The meter is arranged so that the disc revolves twenty-five times per minute at full-load for all capacities, the direction of rotation being from left to right.

RECORDING MECHANISM

The design of the recording mechanism should be such as to insure a continuous accurate summation of the performance of the disc. Intricate design is very objectionable. A train of gears and pinions with suitable pointers and dials has been almost universally adopted. Ample reduction of speed is obtained by the use of a worm and gear. A train of gears is introduced between the meter shaft and the worm and gear so that the speed of the worm is small. This arrangement for obtaining a large gear ratio has many features of advantage.

Careful investigation of effects giving rise to inaccuracy, such as the formation of verdigris, has resulted in the working out of processes for the preparation of the materials so that the active




FIGS. 5 AND 6—DIAGRAMS SHOWING CONNECTIONS WITH AND WITHOUT SERIES AND SHUNT TRANSFORMERS

surfaces are not acted upon by the air. It has been found also that at bearing points unlike metals give more efficient service than when the surfaces are of the same material.

ENERGY LOSSES

In the metering of transmitted energy a certain amount is consumed in the measuring device resulting in a corresponding diminution in the total amount transmitted. In commercial meters of efficient design such diminutions or losses are very small, being within four-tenths of one percent in a meter of the smallest capacity manufactured. The losses are principally in the shunt magnetic circuit which in service has a constant energy consumption, irrespective of the meter capacity.

### ACCURACY FORMULA

If, when making a service test of a wattmeter, it is desired to find the number of watts registered by the meter by counting the number of revolutions of the disc, the following formula may be applied:—

$$\text{Watts} = \frac{R}{T} \times K$$

Where $R$= number of revolutions of the disc in a given time $T$

$T$=time in seconds of revolutions $R$.

$K$=constant, which is the product of the volts and amperes marked on the face of the dial multiplied by 2.4 (for single-phase meter).

### ACCURACY

In Fig. 7 is shown an accuracy curve of a meter of the type being described. The meter is seen to be less than one percent slow at 150 percent load, which load it can carry continuously; while at two hundred percent load it is one percent slow. From 100 percent down to 50 percent load it is less than three-tenths of one percent fast. From 50 percent down to two percent load its inaccuracy varies from two-tenths of one percent fast to zero percent.

It is common practice to seal meters before shipping from the factory. Such seals give assurance that, when the meter is received by the consignee, it is as the manufacturer would have it, in that it has not been tampered with or its original adjustments altered and that it is ready for installation and accurate.

### LARGE CAPACITY METERS

Metering transmitted energy in circuits of low potential but exceeding a certain ampere capacity is accomplished by the use of current (series) transformers, and in circuits of high potential, with series and shunt (voltage) transformers. These transformers are generally made of such ratio that five ampere, 100-volt meters may be used. The design of these transformers is such that the accuracy of the meter registration is not impaired, i. e., the accuracy of the ratio of transformation with the meter in circuit is well within the specified meter accuracy. The dials of meters installed in combination with series and shunt transformers are arranged to read direct and require no multiplying, while the ratings (current and voltage) are those of the line.

STANDARD INSTRUMENTS—CHECKING

One serious difficulty which has been experienced by commercial distributors of electric power is in the standard instruments with which the service meters are compared, the average of standards being in many cases inferior in general performance to the service meters themselves. The difficulty is ordinarily caused by the difference in the characteristics of the various instruments which are compared. The ordinary service meter has a high degree of accuracy at all loads while the ordinary indicating instrument has a much less range, and the readings, which are very accurate at full deflections, are only approximately so at small deflections. For example, an indicating wattmeter may be graduated in divisions which are one percent of the full deflection. At full-load, an error of one division would therefore be one percent. At one-tenth

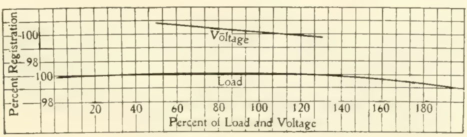



FIG. 7—ACCURACY CURVES

Lower curve shows effect of load variation on accuracy, voltage and frequency being constant. Upper curve shows effect of voltage variation on accuracy, load and frequency being constant.

load, an error in reading of one division would be ten percent. Moreover, instruments of this class, as ordinarily constructed, are not apt to be so nearly correct at low readings as at high readings. It follows, therefore, that there is a liability of incorrectness in the readings taken low down on the scale, on account of errors in the instrument and also on account of the fact that small errors in the readings involve relatively large percentage errors.

An integrating wattmeter which registers upon a dial may, however, be operated with a small load for a greater length of time thereby making the same number of revolutions as would be observed at full-load in a correspondingly less time. It follows, therefore, that the integrating meter can be read with a high degree of precision at all loads. In many cases, integrating wattmeters have been condemned when the fault was in the errors of the low part of the scales of the indicating instruments with which they were compared.

The advantage of a long working range in making measurements of various magnitude is apparent, since a single instrument can be made to cover a much wider field.

When one standard instrument is used for the testing of light loads, another of larger capacity for full-load, and a third for checking the readings on overloads, it is a very rare occurrence to have the three instruments harmonize so as to form an uninterrupted curve on the test sheet. Ordinary instruments used consecutively upon a test, vary in accuracy and cause breaks in the performance curves at points of change, thereby destroying the value of the results. Inaccuracy, such as that shown by the heavy line in Fig. 8, has been called to the attention of manufacturers when the capabilities of the

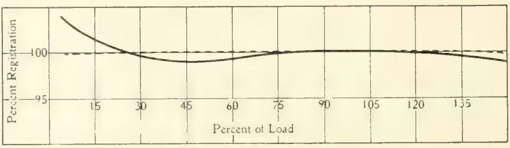



FIG. 8—ACCURACY CURVES

Showing apparent discrepancy resulting from use of different standard instruments on light and full-load during process of checking.

integrating meter in question were found to be in reality as shown by the dotted line. The error was due to differences in the instruments used in checking the meter.

The loads or ranges at which the calibration of an integrating meter is made will also materially affect the accuracy of its calibration. It follows that, in the use of standard meters for correcting other meters where the former is in error to the extent of but one quarter of one percent at full scale, and two and one-half percent at one-tenth scale, the calibration of an integrating meter at the latter point would actually be in error as shown in Fig. 9.

Line testing is usually at loads from one-tenth to full-load, correction for the latter calibration being made by shifting the permanent magnets and for the one-tenth load calibration by the friction compensation. The closest possible setting by this latter means at one-tenth load will give an error of from six percent to twelve percent (+in the above curve) at two-tenths load and may even cause the disc to creep on voltage alone.

Maximum accuracy in modern meters at low range is best checked by means of instruments with large range of capacity because the line calibration at light load can then be made four-hundredths load or below.

### OPERATING CONDITIONS

*Varying Voltage*—Essentially, a meter must be capable of operating over a wide range of voltages without impairment of accuracy. In a design where the greater portion of the magnetic lines pass across the small air gaps of the shunt magnetic circuit and therefore do not pass through the disc, the smaller portion only being effective, a comparatively wide variation of voltage has a very small effect on correct registration. An illustration of this is given

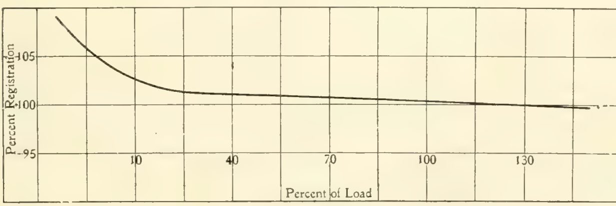



FIG. 9—ACCURACY CURVE

Showing discrepancy resulting from use of standard instrument having small error at full scale and decided error at light loads.

in the form of a curve in Fig. 7 where, for a variation of voltage greater than ordinarily experienced in commercial systems, an error of only approximately one percent is noted.

*Varying Load*—Little difficulty has been experienced in obtaining accuracy of registration at the larger loads but accuracy at light loads is a distinctive feature of meters of more recent design. A meter is now relied upon to record correctly the minutest consumption of energy. This is an important factor in the earning capacity of distributing plants.

*Creeping*—Many of the older forms of meters were given to "creeping". This is the term applied to a movement of the disc under the influence of shunt field alone, i. e., with no current flowing in the series coils of the meter. It was due to a combination of several causes. For example, a magnetic unbalance in the shunt ele-

ment produces a condition very sensitive to vibration and variations of voltage. Proper design, construction and adjustment will render a meter inherently free from such inaccuracy.

*Power-factor*—Many circuits, such as those feeding induction motors, are purely inductive, but single installations may have incandescent lamps and non-inductive load as well as arc lamps and motors. The power-factor under these conditions can vary from 0.55 to unity.

The resultant torque exerted on the coils of a meter in circuit with an inductive load is not proportional to the product of the virtual amperes as measured by an indicating instrument, but to this product multiplied by the power-factor of the circuit. As previously stated, the shunt field is so designed as to be displaced in phase from the series field so as to produce the necessary angle of 90 degrees. As actually accomplished the element $A$-$A^1$, Fig. 2, has an initial lag angle of about 90 degrees and with the complement of the coil $P$, a short-circuited conducting secondary placed in an adjustable manner directly above the gaps in the shunt magnetic circuit, produces an induced magnetic field which, acting with the above, readily gives a 90 degree lag compensation for the potential circuit, the accuracy of this compensation on inductive loads not being affected by a considerable variation of frequency above or below normal.

By using the above principle inductive or non-inductive energy is accurately measured since the disc $C$ has a maximum torque when the current in the shunt field lags 90 degrees behind the e.m.f. of the circuit with a non-inductive load; and as the power-factor decreases with the inductive load, the shunt field comes more nearly in phase with the e.m.f. of the circuit, where the torque diminishes, becoming zero when the shunt field is in phase with the lag circuit e.m.f. This latter is the condition of a circuit having a lag of 90 degrees or wattless current, i. e., a power-factor of zero.

*Frequency*—As many of the smaller plants do not operate generators in parallel, it is no rare occurrence that two circuits from different machines vary in frequency as much as ten percent owing to different speeds of the generating units, thus subjecting the meters to operating conditions other than those for which they were designed. The design must, therefore, be liberal or it will fail to meet the commercial requirements. As shown in Fig. 10, inaccuracies due to such variations have been very much reduced. When used on frequencies differing radically from those for which they are designed—such as a 60 cycle meter on a 133 cycle circuit—the meters will show

only a very small error on non-inductive load. An instrument temporarily installed on a frequency of 125 or 133 cycles is made adjustable for use on a circuit of lower frequency such as 60 cycles by removing a form of insulation that is applied to the coil $P$ shown in Fig. 2.

*Temperature*—Since the retarding eddy currents induced by the permanent magnets are affected by changes of temperature of the disc in exactly the same ratio as those induced by the actuating currents, meters of this type are unaffected by changes in tempera-

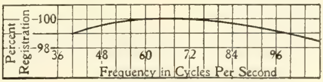



FIG. 10—ACCURACY CURVE
Showing effect of variation of frequency on registration of meter, load and voltage being constant.

ture considerably greater than would be found to seriously affect the operation of meters of other types.

*Effect of short-circuits and external fields*—The permanent magnets are effectually shielded from stray fields which would tend to demagnetize them and thereby cause the meter to operate inaccurately. The considerable distance between the current coils and permanent magnets and the heavy iron supporting frame act as a shield to the permanent magnets thus maintaining reliable registration. Stray fields projected from bus-bars or cables carrying heavy currents do not affect the registration owing to the concentrated field of the measuring elements.

# THREE-PHASE—TWO-PHASE TRANSFORMATION

EDMUND C. STONE

THE notation explained by Prof. Chas. H. Porter in the September issue has been applied in the following article to the flow of current in the several windings of two transformers connected in the ordinary method for transforming from a three-phase to a two-phase circuit. The transformers are for convenience assumed to have equal numbers of turns in the primary and secondary windings, and the no-load currents are regarded as negligible.

The transformer connections are shown in Fig. 1, the percentage of winding between taps being indicated. The e.m.f. induced in the secondary of transformer *A* will be equal to the e.m.f. impressed on the primary and in phase with it, while the e.m.f. induced in the secondary of transformer *B* will have the same value, but will be displaced 90 degrees in phase.

Now suppose a non-inductive load be placed on transformer *B*, there being no load on *A*. A current will flow in the secondary, which will be balanced by a current 1.15 *times that* in the primary (since there are 86.6 percent of the total turns in circuit, and currents are inversely proportional to turns). This current must flow through the primary of transformer *A*, and since tap 3 is at the middle point of the winding, it will divide equally and flow in opposite directions through the two halves; hence the winding acts as a balance coil. Since the current is in phase with the e.m.f. of transformer *B*, it is in quadrature with the e.m.f. of transformer *A*. If, on the other hand, a non-inductive load is put on transformer *A*, when there is no load on *B*, a current will flow, equal in both windings, and of course in phase with the e.m.f. of the transformer. In one of the assumed conditions, the primary winding of transformer *A* acts as a balance coil for the current of transformer *B*, and in another it carries the primary current of transformer *A*. It may carry both currents simultaneously, and with practically no interference or interaction between the two. The resultant current in the primary winding of transformer *A* will then be made up of two components:—

(a) The current due to the load on *A*, equal to the secondary current and in phase with the e.m.f., flowing in the same direction throughout the winding, designated as $I'$.

(b) The current required for transformer *B*, equal to half the

current in the primary of transformer $B$ and 90 degrees out of phase with component (a), flowing in opposite directions in the two halves of the winding, designated as $I''$.

This is the ordinary arrangement for three-phase—two-phase transformation. The conditions are shown graphically in Fig. 2, which represents the currents flowing at point *3* (Fig. 1), where transformer $B$ is tapped into transformer $A$. At any moment the currents flowing toward this point are equal to those flowing away from it; hence the following relations hold:—

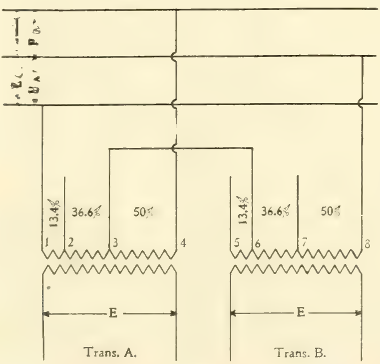



FIG. 1

$I_{8,3}$ = current in primary of transformer $B$ $= 1.15 \times$ current in its secondary.

$I''_{3,1} = 0.5\ I_{8,3}$ = that part of current of transformer $B$ which flows through primary of transformer $A$ between taps *3* and *1*.

$I''_{3,4} = 0.5\ I_{8,3}$ = that part of current of transformer $B$ which flows through primary of transformer $A$ between taps *3* and *4*.

$I'_{3,1}$ = current in winding *3,1* of transformer $A$ due to the load on its secondary.

$I'_{3,4}$ = current in winding *3,4* of transformer $A$ due to the load on its secondary. Since the direction of the load component is the same throughout the winding *1,4*, $I'_{3,4} = -I'_{3,1} = I'_{1,3}$.

$I_{3,1}$ = resultant of $I''_{3,1}$ and $I'_{3,1}$ = total current in primary of transformer $A$ between taps *1* and *3*.

$I_{3,4}$ = resultant of $I''_{3,4}$ and $I'_{3,4}$ = total current in primary of transformer $A$ between taps *3* and *4*.

The vectors $I_{8,3}$, $I''_{3,1}$ and $I''_{3,4}$ depend upon the load in transformer $B$. They are zero when its load is zero, so that $I'_{3,1}$ and $I'_{3,4}$ under this condition represent the total primary current of transformer A.

The vectors $I'_{3,1}$ and $I'_{3,4}$, representing the *load* current in transformer $A$, become zero when its load becomes zero, but with no-load on this transformer, there is still a current, $I''_{3,1} = I''_{3,4} =$

½ primary current of transformer $B$ flowing in the primary winding. In this case, if the load on transformer $B$ is non-inductive, the current in transformer $A$ is displaced 90 degrees from its e.m.f.

When the two transformers are equally loaded, so that a current $I$ is flowing in each secondary, $I_{8,3} = 1.15I$, $I''_{3,1} = I''_{3,4} = 1.15I \div 2 = 0.575I$, $I'_{1,3}\ (= - I'_{3,1}) = I'_{3,4} = I$, and since, by vector addition, $I'_{3,1} + I''_{3,1}$ (i. e., $\sqrt{1^2 + 0.575^2}\ I) = I'_{3,4} + I''_{3,4}$; hence $I_{3,1} = I_{3,4} = 1.15I$. The angle between $I'_{3,1}$ and $I_{3,1}$ is 30 degrees, since its cosine is $1 \div 1.15$ or 0.866. Hence the angle between $I_{8,3}$ and $I_{3,1}$ is 120 degrees and similarly the angle between $I_{8,3}$ and $I_{3,4}$ is 120 degrees. Therefore the three-phase currents are balanced and in phase with the generator e.m.f's.

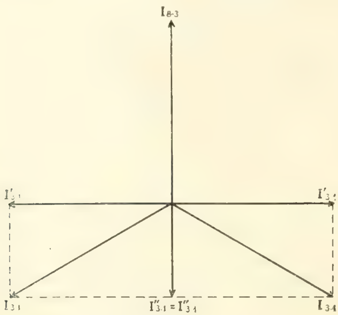


FIG. 2

Whenever transformer $B$ is loaded, the current in the primary of transformer $A$ is greater than it would be if transformer $A$ were merely carrying its own load. With both transformers at full load, this additional current $I''_{3,1}$ and $I''_{3,4}$ in Fig 2 = 0.575 of the full-load current, and the additional copper loss is $0.575^2$ or 0.333 of the copper loss due to the load. Since the copper loss of the primary winding represents about one-half of the copper loss of the transformer the total copper loss is increased approximately sixteen percent.

## CORRECTIONS

Owing to some accidental changes in the forms of the September issue after the page proof had been OK'd, the following errors occurred:

In the article on "Synchronizing" two entire lines were omitted on page 494 after the second paragraph as follows,—"In order to clearly explain the instrument's action the three following typical conditions are assumed:—"

In the article on "Notation for Polyphase Circuits," the equation at the bottom of page 500 should read,

$I_{B''B'} = I_{B'B} + I_{B'A'} + I_{B'C} = I_{B'B} - I_{A'B'} + I_{B'C'}$. On page 503 the radical sign is omited in the expression, "$200 \div \sqrt{3}$ or 127."

THE

# ELECTRIC JOURNAL

VOL. IV. NOVEMBER, 1907 NO. 11.

**Economic Reasons for the Success of Interurban Roads**

The abstract of the article on "Emancipation by Trolley," by Mr. Teague, in this issue of the JOURNAL, is of more than usual interest. The statistical figures given are striking and the predictions regarding the future of interurban electric railroads are worthy of close consideration. In these days of trusts and combinations in nearly every trade, it is a matter of note to find railroad corporations in a number of our states, such as Indiana, divided into two classes; one class using steam and the other electric motive power. Mr. Teague tells us that there have been upwards of $50 000 000 spent in building and equipping interurban trolley roads in Indiana, that the investment has been highly profitable and that the roads are earning liberal returns on a capitalization of $80 000 000.

There are sound underlying economic reasons for the success of interurban railroads such as he describes. The reasons lie in certain advantages which railroads employing electric motive power enjoy as compared with lines operated by steam engines. These advantages relate to both the earnings and the operating costs. The equipment and method of operation of interurban roads particularly suits them for operating a frequent service with headways of one hour, one-half hour or less. The cars on these lines are provided with very high motive power per car. They weigh from thirty to fifty tons each and are often equipped with electric motors of three hundred to four hundred horse power capacity, capable of carrying large overloads for short periods. Owing to the large amount of power available, they can be operated quickly and easily. They stop frequently and will run around curves and over grades that are impossible to cars or trains that are not provided with high power per ton to be moved. They can be run through city streets and on tracks that follow the street and highway grades. The size and power of ordinary steam locomotives is fixed and hence a locomotive, capable of hauling a good sized train, cannot be operated economically with one or two car trains. With electric service multiple-unit control may be used and cars operated either in long trains or one car at a time as the demand may justify. In short, electric

cars are operated to afford maximum convenience to travelers. The frequent service, ease of access and general attractiveness of interurban car service develops high railroad earnings. The passenger earnings are often two, three, four or five times as great as steam railroads could earn in the same or a similar territory.

So convenient is trolley service as compared with steam service for short-haul passenger business, that where there is competition between the two systems for local travel, the trolley roads get substantially all of it and, as Mr. Teague argues, even if the steam roads cut their rates to meet or go below the trolley road fares, the convenience of the trolley service will control the traffic and retain the business.

There does not appear to be any practical reason why there should be a division of interest between interurban electric roads and steam roads. Certain advantages have enabled trolley roads in many sections to come into the territory of steam railroads and take much of their trade and, in addition, build up much traffic that steam railroads could not profitably develop. Why have not the steam railroads taken advantage of the means that have been effectively used by electric trolley lines? They have had every opportunity to profit by electric operation. Their organizations are established and have wide credit. They can generally get money much more economically than trolley roads. It has been a recognized principle among railroad men that branch lines and feeders to large railroads are profitable beyond the earnings of the branches and feeders because of the business brought to the main lines by feeder systems. Trolley roads, as originally constructed, are essentially branch lines and short sections. They develop business; they pick up travelers and freight at first hand. In fact, they are great originators of traffic and are especially effective in securing just the kind of business that is recognized by steam railroads as non-competitive and their surest source of profit. Short trolley lines, when first constructed, may not reach competitive points on steam railroads. They will then deliver their through business to a steam railroad without direct competition and compete only for the local traffic. Under such circumstances they often benefit steam railroads, but they are always likely to reach competitive points by building additional mileage or to become competitors to steam roads instead of feeders, by joining together until complete systems are formed, or, again, trolley lines may be bought by a steam railroad to gain competitive advantage over a rival.

Many steam railroads could equip their local and branch lines

with electric motive power and conduct a frequent and convenient service at much less expense than trolley roads are doing on lines parallel to the steam railroads. Steam railroads have invited trolley competition by failing to give the service that can be profitably rendered by electric operation. The result in Indiana, as pointed out by Mr. Teague, has been that the railroads have permitted one thousand miles of competitive roads to be built in their territory. They have let these roads get started on a profitable basis and in a way which allows them to secure the non-competitive or first-hand business along their lines. The steam roads have allowed this to be done when the opportunity to secure this business was within their control and when they could have done it first with every advantage in their favor.

Mr. Teague says that two thousand miles of additional trolley roads are projected in Indiana. This mammoth increase seems larger than even the most optimistic trolley road enthusiast could expect in this one state in the near future.

Thus far trolley roads have selected for their operations only the best and most populous sections of the country. Their success depends upon securing large passenger earnings. Frequent service is required to secure large earnings and unless the population on a line is sufficiently large to pay a profit on frequent electric car service, trolley road operation will not pay. Trolley roads will grow in mileage until the earnings, in the new territory available for extensions, will not pay a profit.

The question is, has the limit been reached or approximated in such states as Indiana, and further, cannot trolley roads be operated to better advantage in conjunction with steam roads, where these already exist, than as independent enterprises in competition with steam roads?

F. Darlington

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**Circuit-Interrupting Devices**

The series of articles started in this issue of the Journal on "Circuit-Interrupting Devices" deals with a class of electrical apparatus of especial importance. In the earlier days, when voltages were comparatively low and generating station capacities comparatively small, this class of apparatus did not present problems which were very difficult of solution. However, as voltages have increased, and as the generating capacity of single and collective units have assumed such immense proportions, this sub-

ject takes rank with the most important to be handled by the electrical designer. Generally it is not fully appreciated that this apparatus, especially circuit breakers, should receive the attention of the best engineering ability and experience. The conditions of service and requirements are so varied that not only the design should be given careful attention but the applications of the apparatus should be made with the best of judgment. While it is highly important that simplicity and sureness of operation should be the first consideration, yet as it is necessary to protect circuits against a variety of abnormal conditions, it is only by the closest attention to design, and proper application to suit the particular conditions, that the most satisfactory results are obtained.

T. S. Perkins

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**Power-Factor Correction**

In the article on "Synchronous Motors for Improving Power-factor," in the August issue of the Journal, the following features were considered:

1—The most efficient point to which the power-factor should be raised.

2—The advantage in causing a synchronous motor to give out mechanical power in addition to improving the power-factor.

3—The advantage derived by using a synchronous motor in a specific case.

In this issue Mr. Young has suggested a graphic chart for determining quickly the power-factor improvement obtainable by the use of synchronous motors. The graphic calculator provides an interesting method of determining the capacity of synchronous motor necessary to accomplish certain results. It also provides a very convenient method of determining just what the results will be in regard to power-factor improvement and the reduction in generator load by the use of a synchronous motor of given k.v.a. capacity. It further shows just what these results will be when the mechanical output of the synchronous motor is varied; for instance, it indicates the net results in the circuit when the synchronous motor is developing its rated k.v.a. capacity in mechanical power and not furnishing any leading current for power-factor improvement. Or, it will show these results when the synchronous motor is floating on the line; that is, furnishing full k.v.a. leading current and not furnishing any mechanical power. Further, it will show the results in power-factor improvement and reduction in the generator load at any points between the two extreme limits.

Synchronous motors of certain capacities are more or less standard and it is often desirable to determine quickly just what result a synchronous motor of given capacity will accomplish in the system. The graphic calculator provides an excellent method for such determination.

As the calculator is drawn in percent of generator k.v.a. loads, the capacity of synchronous motor required to accomplish certain results may be quickly obtained, the only calculation necessary being that to determine the vector sum of the true and the wattless component of the power in the motor in order to arrive at the k.v.a. capacity of the motor, and that may be obtained directly by scaling the distance on the chart with a pair of dividers.

William Nesbit

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**The International Edition**

The rapid growth in the circulation of the Journal has made advisable a change in the method of handling our foreign business. Hereafter a separate edition of the Journal will be sent to all subscribers in Europe, Africa, and Western Asia. Last month the new edition was sent out to all subscribers in Great Britain and with the present month the entire eastern foreign mailing list is turned over to our London office. This change has been found desirable both on account of the increase in our foreign circulation, and because of the delay in receipt of numbers and the liability of their being lost in transit when shipped from our main Pittsburg office. By handling all of this business from London we will be able to give more reliable service and avoid the delays incident to long distance correspondence.

The International Edition will contain all that appears in the regular issue and also additional matter in the way of news items, advertisements, personals, etc., which will appeal more especially to its readers. Thus the center of distribution will be much nearer the foreign subscribers and the Journal will be more suitable for their use. It is evident from the fact that foreign subscriptions have come to us so freely that there is a larger field for the Journal which will be reached by the special service now inaugurated.

The Publication Committee

# CIRCUIT-INTERRUPTING DEVICES—I

## GENERAL

F. W. HARRIS

DEVICES which have the one function of opening an electric circuit may be classified broadly as switches, fuses, and circuit breakers. Other devices may open the circuits as an incidental feature. Four general considerations are involved in the design of any circuit-interrupting device.

First—To provide means for carrying the rated current of the device without excessive drop or heating, and, in addition, such overloads as will be met in practice.

Second—To insulate all live parts for maximum potential in a permanent manner, both electrically and mechanically.

Third—To provide mechanical means for opening the circuit. This may take a variety of forms as noted below.

Fourth—To prevent or render harmless any arcs that may form.

The relative importance of these considerations depends on the case at hand. Thus the first depends on current and becomes insignificant on low currents while the second depends on voltage. The third is a question of application and mechanical design, while the fourth is dependent on both voltage and current.

### CARRYING CAPACITY

The question of carrying capacity divides itself into heating of material in the switches and heating at the contacts. The first is not essentially different from that met in all electrical apparatus. The second is complicated and difficult of analysis. Conditions of surface, current density and pressure between surfaces seem governing factors. The tendency is towards heavy unit pressure, but it is found that there is a maximum above which additional pressure causes no gain.

Fig. 1 shows typical curves of voltage drop between two contacts, the current being maintained constant and the pressure varied. It may be noted that the drop across the contacts decreases rapidly with pressure up to a certain critical pressure, but that when in this particular case the unit pressure becomes 3 000 pounds, added pressure does not decrease the drop. The heating of the contacts due to contact resistance is, of course, proportional to the drop at the contacts.

### INSULATION

The insulation problem is complicated by the presence of arcs with their resultant conducting vapor and excessive heating. Difficulties with insulation increase much faster than the voltage, and there is a practical maximum voltage for each type of device that cannot be exceeded without endangering its factor of safety. This maximum is probably the limiting factor, as insulation difficulties seem much more acute on high voltages than do any of the other three considerations.

### MECHANICAL ARRANGEMENT

Circuit-interrupting devices may be automatic or non-automatic. If the latter, their operation depends solely on the action of the operator. If the former, they may depend on the action of the operator but they must also depend on the occurrence of some predetermined condition, such as maximum or minimum current or voltage. Or they may be dependent on the speed of a generator, pressure of gases or liquids, or numerous other conditions. They may also be made to respond to changes in direction of the current as well as its magnitude, and they may be so arranged that the determining condition is also modified by time.

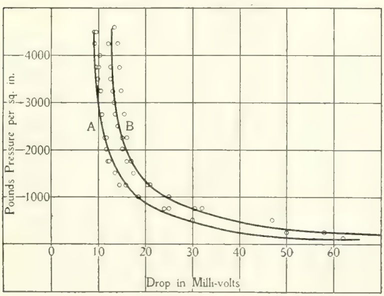


FIG. I—TYPICAL CURVES OF VOLTAGE DROP BETWEEN CONTACTS

Curve *A*—Current density 888 amperes per square inch.

Curve *B*—Current density 1333 amperes per square inch.

In general it may be said that fuses are always automatic, switches always non-automatic and circuit breakers either automatic or non-automatic. Circuit breakers in general are so arranged that a spring or gravity tends to open them, and they are held closed by latches or toggle mechanisms. This explains the difference between a switch and a non-automatic breaker.

### METHOD OF HANDLING ARC

When an electrical circuit is interrupted by any device the prin-

ciple is that of introducing into the circuit a high resistance value. When a switch is opened the resistance of the air path is introduced between its jaws. The current generally maintains itself for a small interval of time depending on the speed at which this resistance is introduced. During this interval practically all of the stored energy of the circuit must be dissipated as well as the energy due to the impressed voltage of the circuit acting on the high resistance path. A circuit may be opened so quickly that the stored energy is not discharged at the switch, but must discharge elsewhere. The second source of energy, namely, the loss in the high resistance path, is always present. This energy is converted into heat, and as the space is small high temperatures are instantly reached; metal parts are vaporized and the hot metal vapor has a comparatively low resistance as compared with air.

The aim is to prevent the formation of low resistance vapor or to successfully counteract its effects. The first and most obvious way is to provide such length of air path and speed of opening as will make the energy involved small and the consequent arcing insignificant. If the amount of current is very large, or if the voltage is very high these methods become impractical and means must be provided to extinguish the arcs. At present four commercial methods are used—oil, magnetic blow-out, expulsion and enclosure.

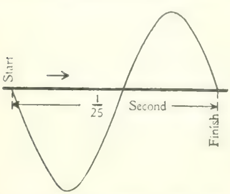


FIG. 2—OSCILLOGRAM OF CURRENT WAVE OF FUSED CIRCUIT BREAKER OPERATING ON SHORT-CIRCUIT

*Oil*—The use of arc insulating liquid has much to commend it. It is cheap and provides an arc quenching, an insulating and a cooling medium. It has the disadvantage of being inflamable and more or less objectionable on account of splashing out, and discoloring and soiling surrounding objects. For high voltages it has no competitor. For low voltages the above objections seem to prevent its use. On direct-current circuits the objection is sometimes made that oil carbonizes. This, however, is not borne out in practice.

*Magnetic Blow-out*—This principle is largely used both on direct and alternating current, being, of course, much more applicable to the former as the presence of alternating flux sets up eddy currents in surrounding metals. The arc is broken in a magnetic field, the current-carrying path being violently repelled. This method is

noisy and care must be taken to properly dispose of hot metal vapor. On large currents having wide contacts and therefore long air gaps in the magnetic circuit it becomes difficult to produce the necessary concentration of flux.

*Expulsion*—Expulsion devices depend on the expansion of air in a tube or other confined space to break the arc.

The majority of expulsion devices such as expulsion fuses, plunger switches, etc., are in reality air blowout devices. That is they depend for their action on a current of cold air moving at a high velocity to open the arc. This is the most obvious way to open arcs and it should be noted that the very term "blowout" indicates a current of air. The early pioneers in this field conceived this method and the Thompson-Houston arc machines utilized the air pressure from a small blower to prevent sparking at the brushes. It is obviously difficult to provide constant air pressure at a switching device and arrangements are therefore made to cause expansion of the air through the action of the heat of the arc. The pressure is relieved through a small orifice through which the arc must also pass. This method is inherently defective in that an arc must be established before expulsion starts. Furthermore small molten particles are sometimes violently projected to considerable distances thus forming a source of fire risk.

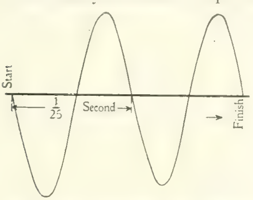


FIG. 3—OSCILLOGRAM OF CURRENT WAVE OF EXPULSION FUSE OPERATING ON SHORT-CIRCUIT

*Enclosure*—In this case the metal vapor is absorbed in the interstices of a solid body. The principle application is with enclosed fuses, in which the metal vapor is broken up by the finely divided filling. Switches might be made on the same principle were it not for the difficulty of making contact through such material.

## QUICKNESS OF BREAK

In interrupting a circuit it is usually desirable to have the break made as quickly as possible. On alternating-current circuits the current curve generally ends on the zero line. Oscillograms taken by breaking the circuit on various devices show that on short-circuits the fused circuit breaker consisting of a fine wire under considerable tension and enclosed in an expulsion tube gives the best results. (See Fig. 2.) This curve is a fairly representative one and shows that

the fused circuit breaker opened the circuit in one twenty-fifth of a second after a short-circuit occurred. This is due to the fact that the wire was quite small and under considerable initial tension. On the occurrence of a rush of current the wire became heated and was violently ruptured, and the arc blown out by expansion of the air in the tube.

Next in order of quickness comes the expulsion fuse in which wire is not under tension and in which the arc is simply ruptured in a small tube. An oscillogram for this type is shown in Fig. 3. Circuit breakers in general take about twice this time to open, as they have considerable inertia. It should be noted, however, that the actual duration of break is not represented by these curves as some time must elapse before the circuit starts to break, i. e., on the occurrence of a short circuit several things must happen before the device actually starts to draw an arc. For example, in an automatic circuit breaker the tripping coil must attract its armature, the armature must release a latch or toggle, the mechanism must then

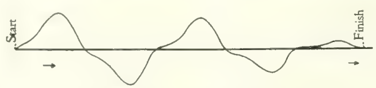


FIG. 4 — OSCILLOGRAM OF CURRENT WAVE OF "SWEEPING ARM" TYPE OF CIRCUIT BREAKER OPERATING ON HEAVY CURRENT

start and in most cases move over a considerable distance before the arc is started. In the fused circuit breaker the wire must be raised to such a temperature that its strength is impaired enough to be ruptured by the pull of the arm and this arm must start to travel. It is possible that in both above curves the actual duration of arc is one-hundredth of a second or less.

A case in which the duration of the arc was long is shown in Fig. 4, in which case the arc was opened in air by a sweeping arm. Each peak of current wave is lower than its predecessor until finally the arc is unable to establish itself. It shows clearly why air break switches are impractical on high tension circuits.

From the above it will be evident that the design and application of circuit-interrupting devices calls for considerable experience and that each case permits of several solutions. In the articles to follow, the operation of some of the various types of circuit-interrupting devices will be considered.

# ARTIFICIAL LOADING OF LARGE HIGH VOLTAGE GENERATORS

N. J. WILSON*

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THE apparatus required for artificially loading large high voltage generators is so much subject to conditions existing on the site at which the generators have to be tested, that it is more or less impossible to lay down any hard and fast rules to work upon when full-load tests on such machines have to be caried out. If it is possible to run an auxiliary plant such as rotary converters or motor generators fed through static transformers from the main generator, a steady load can readily be obtained by loading up the auxiliary plant on water tanks such as are frequently used for voltages up to 2 000. For taking steam consumption tests on steam driven electrical plants, however, it is preferable wherever possible to load the generator on a direct non-inductive resistance. For the voltages considered in this article, i. e., from 6 000 to 12 000 volts, it is generally admitted that the only practical form of resistance which can be used, is the purest water obtainable, and it is owing to the great difference that exists in the conductivity of the water available at different places that the chief difficulty is found in determining the size of apparatus required in different places. This is shown by the comparative resistance tests taken on various water which the British Westinghouse Company has had to use for testing purposes.

The writer has found that the chief points to be taken into consideration in designing such apparatus are as follows:

1—The electrical resistance of the water available for use.

2—The amount of water supply available.

3—Means of saving water used throughout the test.

4—The regulation to be obtained when working.

5—Lastly and most important, absolute safety to the tester who has to operate the apparatus adopted.

The first two of these items determine the dimensions of the tanks to be used and upon these in turn depend to a great extent the regulation to be obtained under working conditions. For instance

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item (1) fixes the voltage which can be safely put across the electrodes in the tank, and item (2) controls the amount of energy which can be absorbed by the tank. Again, it is obvious that the higher the temperature at which the water in the tank is worked, the greater the energy absorbed. Care has to be taken, however, to keep this temperature as constant as possible in order to ensure the obtaining of a steady load, and in practice it is found that it is best to work the water at such a temperature as will prevent the formation of vapor. Item (5), namely, the safety of the tester while using the tank, brings one to the consideration of the material to be used in its construction. In this connection it may be mentioned that wooden tanks have been used from time to time, but they have always been found to give trouble on high voltages. The saturated wood allows the current to flow through it in parallel with the water and in consequence the wood is first charred and then set on fire. Another disadvantage is that the tester is liable to receive shocks.

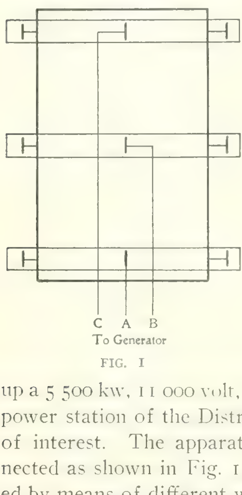


FIG. 1

For the latter reason alone, therefore, it is best to use material that can more readily be satisfactorily earthed. To illustrate that the following account of an attempt to artificially load up a 5 500 kw, 11 000 volt, three-phase turbo-generator at the Chelsea power station of the District Railway Company, London, may prove of interest. The apparatus consisted of three wooden tanks connected as shown in Fig. 1, the regulation of resistance being obtained by means of different water levels. Other methods for regulation, such as, by moving plates closer together and also by varying the surface of electrode under water without altering the water level, can be used, but the rig required becomes somewhat complicated. Each tank had three electrodes, the live electrode being in the centre and two other neutral electrodes at the ends of each tank. All the neutral electrodes were connected together and joined to the star point of the generator, which was earthed. It may thus be seen that with 11 000 volts on the generator there was a potential of about 6 300 volts betwen the live and neutral electrodes in each tank. A continuous stream of water was kept running through each tank.

It was found that, however carefully insulated the live plates were from the woodwork of the tanks, after the voltage had been on for a short time, the sides of the tank nearest the centre began to fire, clearly indicating that the current was leaking along the wood, thus making it a parallel path with the water. To prevent this, the sides and bottoms of the tanks were lined with glass, the joints being cemented. This answered all right until the water got through the joints and again caused firing of the wood. As it was found very

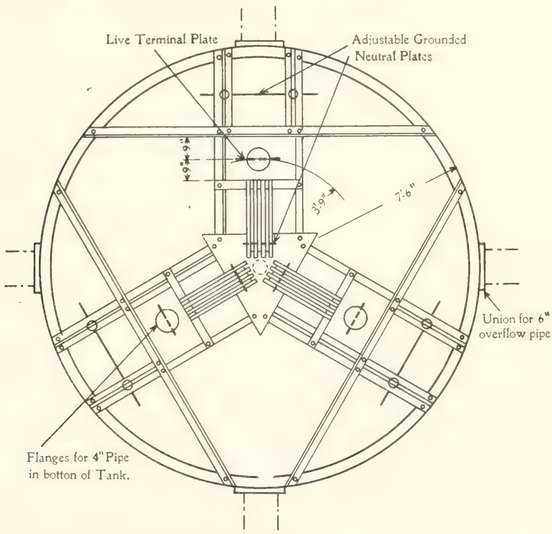



FIG. 2

difficult to get these joints to stay watertight the whole scheme had to be abandoned. The internal dimensions of these tanks were about 17.5 feet long by 1.25 feet wide by 2.5 feet deep. The maximum load obtained on them was 3 000 kw at 11 000 volts and with this there was considerable firing of the wood, rendering it impossible to keep the load on for any length of time. The reason for the live plates being placed in the centre of the tanks and the neutrals at the ends, was to make the apparatus safer for the tester.

Had only two plates been used, namely, one live and one neutral plate, it would have caused the three streams of water at one end of each tank to have a potential of 11 000 volts between them,

thus rendering it dangerous for those in the close vicinity. These three wooden tanks were afterwards replaced by a single iron tank 15 feet in diameter by 10 feet deep. Water inlets were placed at the bottom of the tank at three points right under the position of the three live electrodes and also an inlet was placed in the centre with a continuation pipe to allow cool water to be supplied to the top of the tank in order to assist in keeping down the formation of vapor. The tank was also provided at the top with four outlet pipes and at the bottom with a drain pipe for emptying when necessary.

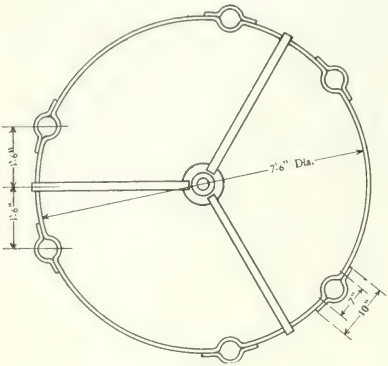


FIG. 3

The arrangement originally provided for electrodes is shown in Fig. 2; from this it will be seen that the neutral electrodes could be moved nearer to the live electrodes by moving them along the slides provided for this purpose. They were all earthed substantially to the framework of the tank which in its turn connected to the neutral point of the generator, thus rendering it impossible to get shocks from the side of the tank. The three live plates are suspended from a wrought iron ring as shown in Fig. 3. The

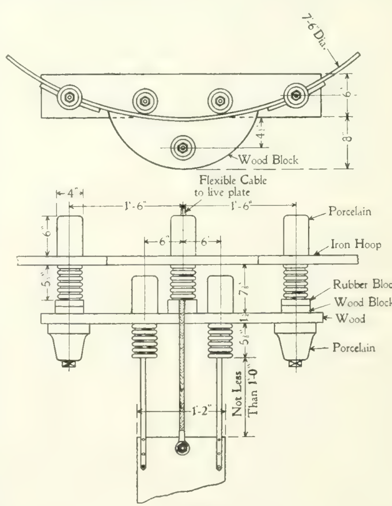


FIG. 4

method of insulating these suspended plates is shown in Fig. 4. From this it will be seen that double rows of high tension insulators come between the metal ring and the live plates; the former of course is earthed, thus preventing any possibility of the tester receiving shocks when lifting or lowering the live plates by means of the rope attached to the hanging element.

After a preliminary run, it was found that the town water supply, which was the purest available, was of such a resistance that neutral plates were not required at all to obtain the loads. Again, with the live plates as at first used, full load current was obtained with only 8 000 volts on the generator. To overcome this the plates were reduced in size, till finally in order to get the full voltage on the tank and at the same time keep the current down, rods of copper were tried as electrodes. This expedient naturally meant that the current density was increased to such an extent in these electrodes that excessive arcing took place both under and at the surface of water. To do away with this arcing it was necessary to use larger electrodes and this could only be done when the resistance of the path between the live electrodes was increased. To do this, the idea was tried of placing 12-inch terra cotta pipes about eight feet high under the electrodes, the top of these pipes coming about two feet below the surface of the water, the bottom of these pipes resting on the base of the tank. This had the effect of cutting down the cross-section of the water between electrodes and so increased the resistance of the path.

With this arrangement the larger electrodes were again used and worked quite satisfactorily at 11 000 volts. The increased section of the electrodes, together with the fact that cool water was kept entering the tank at the bottom of each of the terra cotta pipes, kept down any tendency to arc on the heavier loads. By reducing the height of the pipes by quite a small amount, such as one foot, the load which the tank would take was increased a great deal, as the resistance of the path between the electrodes was thereby rapidly reduced. With water having a resistance such as that of Manchester or Yoker as shown in Table I, such an expedient would not have been necessary. With this tank loads up to 8 000 kw at 11 000 volts could be obtained by increasing the size of the electrodes. A small motor was rigged up to drive a pump for circulating the water. After going through the tank it was again used as feed water, although when the tank was taking heavy loads it was found impossible to save all of it in this way.

The results of an analysis of the various waters used in the test is given in Table I. The comparative resistance tests were all taken under similar conditions and serve to show the variation in water obtainable, and the consequent difficulty when worse specimens only are available. For instance, in the testing department at the Trafford Park Works, Manchester, with a tank eight feet in diameter by five feet deep, when used with the well water given in

TABLE I

| Impurities Found By Analysis | Grains Per Gallon | | | | |
|---|---|---|---|---|---|
| | Manchester Well Water | Manchester Town Water | Chelsea Town Water | Yoker Town Water | Clyde River Water Motherwell |
| Total Solids | 115.64 | 4.92 | 16.30 | 3.36 | 12.95 |
| Inorganic Solids Non-Volatile | 1.4 | 3.86 | ........ | 1.96 | ........ |
| Organic Matter | 114.24 | 1.06 | 2.38 | 1.40 | .. .... |
| Silver | .98 | .19 | .488 | .11 | .78 |
| Iron ($Fe_2O_3$) | .9 | ...... | .456 | .33 | .47 ($Fe_2O_3$) ($Al_2O_3$) |
| Lime ($CaO$) | .67 | .28 | 4.620 | .28 | 2.43 |
| Magnesia ($MgO$) | .38 | .15 | .56 | .19 | 1.54 |
| Sodium Chloride ($NaCl$) | 88.9 | 1.38 | 2.765 | .78 | ........ |
| Carbon Dioxide | ........ | .. ... | 1.729 | 9 | ........ |
| $So_3$ | ........ | ...... | 4.508 | ...... | 1.19 |
| $Na_2O$ | 9.59 | .. ... | ... .. | ...... | ........ |
| Comparative Electrical Resistance* | 1 | 30 | 6.8 | 37 | 48 |

*These results are expressed taking figures obtained for Manchester well water as a unit, this being the most impure tested. Hence Manchester town water has a resistance thirty times greater than the well water and so on.

Table I, it was found impossible to get 1 000 volts across the electrodes without an excessive current flowing, whereas, with the Manchester town water, loads up to 2 500 kw at 9 000 volts could be absorbed with only a two inch water supply. It will be seen from Table I also that the town water was found to have a resistance thirty times greater than that of the well water. Again, at the Yoker and Motherwell Power Stations of the Clyde Valley Power

Company, brick tanks were constructed below ground level for testing the 11 000 volt turbo-generators. These tanks were 15 feet in diameter by five feet deep and they were found to work quite satisfactorily, without any of the difficulty experienced at Chelsea, owing to the much purer water supply.

In conclusion, there are a few necessary precautions which should be taken before attempting to take a full-load run on artificial load on a high voltage generator, viz:—

1—Earthing of all instrument cases in the circuit, so that testers cannot get shocks therefrom.

2—Thermometers on various parts of the generator windings should be tied firmly in such a way, that they can be read throughout test without any necessity for handling them.

3—The rig for hoisting the hanging element should be examined before the test to see that it works freely and stops should be placed so that the plates cannot be accidentally overwound, or drop to the bottom of the tank.

4—The insulators on the hanging element should always be examined and thoroughly cleaned before a test. As these are often in the open air, they are very apt to become dirty and if not cleaned, discharges may take place, causing them to crack, and necessitate the shutting down of test.

5—Careful observation of the operation of the tank lest circulating water supply should suddenly fail, in which case the time taken to greatly increase the load is so short that arcing on the electrodes commences, which may end in a bad short-circuit on the tank.

6—Means of communication between the testing tank, switchboard and the man running the turbine or engine, so that in such an emergency as just mentioned the load may be quickly reduced or taken off altogether if necessary.

7—A complete set of isolating switches should be placed between the main switchboard and tank, so as to cut the latter completely out of circuit when required.

8—A careful examination should be made to see that the earthing arrangements made for the neutral point of the generator and also for the testing tank are adequate and satisfactory.

These precautions, all of them more or less simple, if neglected are apt to result in much needless annoyance and possibly the complete shut-down of an important test.

# OPPORTUNITY*

WALTER C. KERR
President, Westinghouse Church Kerr & Company

IT is a good sign when any one stops thinking of his own welfare and begins to think of the welfare of others. For a man to persistently seek only his individual welfare is plainly selfish. He may get a little, but what he gets is so slim that it can easily slip away. If, however, we produce a welfare so broad as to be for all, every one is sure to get some of it. Anything we possess only for the moment is soon gone. We need things that endure and remain a joy forever. It is therefore no small matter for a band of men, whether they be associated through their work, their play, their society or their religion, to so band together for the common welfare as to produce a lasting condition which will live with them and remain for their children after them.

Welfare is defined as a state of well being, prosperity, freedom from pain or discomfort. Upon this occasion we see something of all these about us. This beautiful building with all its useful facilities is a physical evidence of them. The skill and effort which have brought it into being are a product of this welfare, and the spirit of humanity which has led this community to desire this betterment and to rally around and within it is also a product of this state of well being. It is this spirit of welfare which brings welfare to our midst and gets the greatest use and benefit from it when it comes. The motive of the community makes more for its welfare than any individual or corporation can do for it.

The unselfishness of which I have spoken is the finest feature of welfare. No matter how much any one may wish to help himself in the pursuit of comfort and happiness, it is only when he does it unselfishly that the desired result is really obtained. For this reason, men cannot successfully work alone. They can scarcely think alone. They must go hand in hand, shoulder to shoulder, and work for the common good in order that their portion may be good.

You have noticed that the men who excel in their work, who rise from one position to another, whose words are most listened to in council, and who, from time to time, are chosen to represent their

*From an address delivered at the dedication of the new Welfare Building of the Westinghouse Air Brake Company, July 20, 1907. This building is located near the works of the Air Brake Company in Wilmerding and is under the auspices of the Y. M. C. A.

fellows and to act for them are always men who mingle with others, get close to others, understand others, and therefore constantly gain something which makes them a little bigger and better. Again and especially in the younger men you have seen that those who grow and gain higher positions are the ones who acquire some part of everything in sight. They understand the things about them. They are interested in everything. They take part in everything and make themselves a part of the world they live in, acquiring knowledge here and there as opportunity offers, getting skill through close application to their work, gaining wisdom by listening to those who are wiser than they, and profiting by every experience rather than allowing the lessons of the day and hour to pass and be forgotten. Every live man should learn something every minute, and if he does he will have the best education in the world. Books are good up to a certain point, but a man does not really need to get much from them. Instruction is good, especially for the very young, but good sense will give itself instruction. Learning is not a thing stored far away in libraries and in the minds of men with titles, but it is right here, now, in our day's work, in our evening's pleasure, in our relation to our friends, and especially right in ourselves, when we see, understand, take inside, and keep, a little of everything that goes by. That is practical education, the kind the world needs even more than it does some of the flights, and it is the kind of which most men get the least. All this means embracing opportunities. Some spend all their time waiting for an opportunity as big as a mountain to heave in sight. That kind never comes, but there are a dozen about your own size every day, and they are the bricks of which the wall of your strength should be constructed.

It is well known that all good effort is more easily, quickly, and in many respects better exerted when it has something to center upon. The diligent and helpful men of any community naturally incline to do things for the common welfare, but if this effort is not united it may be so dispersed as to produce little effect. If it can center around some one thing, it is gathered into a strong sustained effort which, by constant addition, grows and grows. This Welfare Building, therefore, becomes the temple of the spirit of welfare and all it stands for; the keeper of your motive; its facilities and appliances become the servers of your best intent. It stands for you as you stand for it. It works for you as you work for it. And it will remain for you and yours longer than you can live for it.

When I look at the opportunities, comforts, and pleasures af-

forded by an institution of this character, which you have justified by being a body of men banded together so firmly and with such good motives as to warrant the creation of this structure, I cannot help think of the contrast all this presents to the conditions under which I worked when I was as young as the youngest boy here and continued to work until I was as old as the average apprentice; how at the age of twelve I was shingling roofs and tacking on laths for the plasterers in a town buried so far in the middle of a far western state that I had never seen a railroad. Then working at several things until I landed at one end of a surveyor's chain, tramping the western prairies, often wading waist deep in the waters of the marshes, sleeping in a tent, eating what I could get, and drinking water so bad that it would not make tea nor coffee, but would turn into something like ink. The best school I had was not as good as your worst one, and I did not have much time to attend it either. Such a thing as a night school was never heard of. The night was the time to sleep, and we did not have electric lights, gas, nor much of anything brighter than moonshine. No one was thinking about organized welfare, and the world, with its facilities, as you know it, was very far away.

It happened, however, that I got hold of a catalogue, from which I selected about half a dozen drawing instruments and a book called "Gillespie's Land Surveying," another on "Elementary Projection," and another on "Shades, Shadows and Perspective," scarcely knowing what these books were about, except that I thought from their titles that they would teach drawing and surveying. From the pictures in the books, I made a drawing board, a T-square, and two triangles, and I well remember mortising the T-square blade into the head, which prevented the triangles running over the left hand edge of the board. Notwithstanding such ignorance of the things you always knew all about, I learned to draw the kind of things these books taught, studied land surveying until I understood it, studied the surveying instruments from the pictures in the books and it was shortly after this that, when working as chainman, the head surveyor found that—although I had never had a transit in my hands—I could run one from what I had dreamed about it, and so I was promoted to transitman. It thus came that I ran a transit on the western prairie when I was only sixteen years old and got a man's wages for doing it. It was then that I learned for the first time that if any one would learn something that no one expected him to do, some one would soon want it done and want him to

do it. I also learned in a good many ways what a day's work was and it was a good deal longer than anything we know of now.

I mention these things, not to tell the story of my life, but just that little piece of it which is necessary to show some of the younger men who live in this land of plenty, surrounded on every hand by things that help them, something I know personally of what a boy can do when his lot is cast so far away from everything that he has to even use his imagination to believe that the things of the world exist.

In the course of time a small foundry grew up in the neighborhood and I used to get the job of running the engine and boiler, fired with wood, Saturday afternoons while the engineer went into the foundry to help pour. Then I got a chance to mold waffle irons and bob sled shoes. In the winter, when the snow was several feet deep on the ground, I used to go to a little grist mill and help the engineer and the miller until I knew every nut and bolt in the engine, the condition of the piston rings, and every step of the process of milling flour. I would walk five or ten miles back into the woods to get a chance to work for a day without pay in a saw mill. When a steamboat landed at the levee, perhaps once or twice a week, I would always run from wherever I was at the first blow of the whistle, get there as soon as the boat, and stay on board, generally with the engineer, as long as the boat was tied up. To have a steamboat go up or down the river was a much bigger day to me than a day's holiday would now be to any of you. Even a corn sheller, a mowing machine, a piano, or a door lock was food for investigation. I lost no opportunity to get them apart and together again and well remember as a boy of fifteen repairing the action of a disabled piano on which most of the hammers stuck.

Now there is a lot of talk about opportunities, and lots of money is being spent in and about Pittsburgh to provide opportunities for young people, all the way from welfare buildings to libraries and technical schools, but I want to tell you that you have a thousand times as many opportunities around you every day as anybody can ever intentionally provide you with, and it is these opportunities that you must see and grasp. As a boy I would have walked a hundred miles to have spent one week in any shop that any of you have ever worked in, and I would have walked from Minnesota to Pittsburgh to have had a tenth part of the opportunities many throw away every day. The real trouble is that you have so many in this

dense civilization that by familiarity they are likely to seem commonplace and be overlooked.

If there is any one thing that this welfare movement ought to do more than any other, it is to teach you all to utilize for yourselves and for the common good everything that is about you. Don't think you have it just because it is near you. You will only have it when you get it. You must reach out to get it and you want to be reaching all of the time, not some other time or when you get more ready, but every day and every minute. Nearly every man does what he intends to do, so look out for your intent and don't get fooled into thinking that it is good when it is only asleep. Keep it active.

The welfare that this building stands for is the welfare of sturdy men and women. When we say a man is a manly man, what do we mean? If we mean he had good manners, we say he is a gentleman. In another respect, we may say he is a good man. We may also say he is a skilled man. But when we say a man is a manly man we mean that he is always to be relied upon even under pressure. A man must make good under pressure. It is not sufficient to simply do the right thing when it is easy, to control temper when not vexed, to be considerate when not crossed, or to appreciate the rights of others when they seem the same as our own. It is when the pressure of resistance constrains away from a natural inclination that we have the chance to show what is in us. That is the time when it will be found whether loose ends have been allowed to develop and flutter idly in the breeze or tangle into stubborn knots.

Resistance is necessary to develop men's characters and the biggest men of the world are the ones who have had to encounter more resistance than you ever knew, but they do not go up against it blindly. If they succeed, they do it wisely, tactfully, and with consideration for others, and for everything with which they are in contact. It is for the welfare of all that all should be strong, and the strong, the good, and the faithful are the ones chosen for the highest duties which their talents permit them to perform.

You have one great example of all these virtues in the man who founded the institution for which you work and its allied interests. I need not tell you about him. I need not tell you whether starting from a small machine shop in a small town he made good in the world's arena, nor need I say anything about whether his voice was always for the welfare of everything about him, but I may remind you of something that you do not all know and that is, when in the

greatest insurance company in the world there was found looseness, carelessness, impropriety, and some even charged fraud, and when there was necessity for selecting three men from the whole United States to stand for the honesty and integrity of further action concerning the interest of the people who hold hundreds of millions of dollars of insurance in this great corporation, one of the three was George Westinghouse.

Welfare is no small thing, and those who successfully wield it have an influence greater than they know. No man can measure the good that will come to the welfare of this community as typefied in this building. Its radius of influence will apparently be within the boundaries of the town in which it centers, but in this town will grow up men and women who will go elsewhere and carry its mission with them, and just as every man is a center of his own world, so is this building the center of a welfare from which will radiate an educational, uplifting, and helpful influence to make better men and women, and make all more competent to live life and enjoy it.

It fosters independence and at the same time illustrates and proves the necessity of dependence. It adds to every man's power part of the strength of his neighbor. It adds pleasure to comfort and enriches every one with the blessing of good cheer. It is yours, and will be what you make it. You cannot make anything better of it than you make of yourself, for in its total effect it will represent the average quality of this community.

I hope you will always remember that it is not the building, it is not its contents, it is not the liberal gift that created it, but it is the spirit that you show and maintain, the spirit of welfare, that will make this institution worthy of its name.

# EMANCIPATION BY TROLLEY*

IN Indiana the people, long ago wearied by the same practices that now breed universal revolt against the steam railroads, set themselves to the task of determining the problem of transportation. And they did a strange and peculiar thing—their first endeavors afforded the steam railroad owners and managers much amusement—they set about building their own railroads.

No longer do the steam railroad interests smile in amusement. Seven years only have passed since the Indiana public went earnestly at this gigantic task.

One thousand miles of track are now in operation; 350 miles are building and will be placed in operation early this year; another 2 000 miles are projected; more than fifty million dollars have been invested actually in these railroad properties; passengers are carried at their convenience in clean and comfortable cars, and for one-half the former fares; parcel and perishable freight goes forward to its destination most expeditiously and at reasonable charges, and the entire complexion of life in the Hoosier state has been changed.

What this system is and what it has meant as a transportation emancipator, is revealed upon cursory examination of a trolley map of Indiana, and a statistical record of the various companies now operating high-speed passenger and freight railroads by electricity in that state. During the present year the line to Louisville will be opened to traffic and a through-train service operated; the line from Lafayette to Chicago will be placed under construction, and the south-eastern lines which are aimed to provide a through service between Indianapolis and Cincinnati pushed nearer to completion.

Each one of the roads operating at present parallels a steam railroad. Operating these existing lines are thirteen principal corporations, each of which has one or more subsidiaries. Total capitalization is $41 150 000 in stock and $43 080 500 in bonds, or slightly more than $80 000 per mile of constructed road. This figure closely approximates the capitalization of the steam railroads of the country, and represents a "watered" value of about $30 000 000 injected in the absorption and amalgamation processes that have been resorted to. Upon this enormous capital—the growth of seven

*Abstract of an article on Indiana Trolley Roads, by Mr. Merrill A. Teague, from *Appleton's Magazine* for July, 1907.

years—the companies are not only paying liberal dividend and interest charges, but are paying heavily for franchise privileges, notably in Indianapolis where the city system takes as a terminal and trackage fee three cents out of every five-cent fare collected in the city limits. In its financial phases, therefore, the solution of this transportation problem has resulted in a manner eminently satisfactory to those who engaged in the task.

In the operation of these roads, there is attained in respect to passenger accommodations, an extreme of perfection. Contrasting this service with what was formerly, and is now, afforded by the steam railroads, one is able to appreciate the measure of the advance made since the installation of the elctric traction service. Table I makes this contrast, showing the conditions of the service on the

TABLE I

| To Indianapolis From | Miles | 1899 Trains Per Day | 1899 Fare | 1906 Trains | 1906 By Trolley Trains | 1906 By Trolley Fare |
|---|---|---|---|---|---|---|
| Anderson | 39 | 6 | 1.10 | 9 | 20 | 0.60 |
| Muncie | 54 | 5 | 1.65 | 7 | 18 | 0.85 |
| Marion | 70 | 3 | 2.10 | 3 | 16 | 1.05 |
| Wabash | 90 | 3 | 2.70 | 3 | 14 | 1.40 |
| Union City | 85 | 4 | 2.55 | 6 | 17 | 1.55 |
| Crawfordsville | 43 | 4 | 1.30 | 4 | 13 | 0.75 |
| Lebanon | 28 | 5 | 0.85 | 5 | 18 | 0.45 |
| Lafayette | 64 | 5 | 2.00 | 6 | 15 | 1.05 |
| Frankfort | 47 | 4 | 1.40 | 3 | 15 | 0.75 |
| Kokomo | 54 | 2 | 1.65 | 3 | 17 | 0.90 |
| Logansport | 77 | 2 | 2.30 | 3 | 12 | 1.25 |
| Columbus | 41 | 6 | 1.25 | 6 | 18 | 0.65 |
| Franklin | 41 | 6 | 1.25 | 6 | 18 | 0.65 |
| Richmond | 68 | 6 | 2.05 | 7 | 14 | 1.05 |

steam railroads before the interurban trolleys came to destroy their monopoly, present conditions, the passenger service provided by the trolleys, and respective rates of fare—all between Indianapolis and the chief cities reached by trolley lines radiating from the state metropolis.

Thus it will be seen that the traction lines, in addition to doubling, trebling and even quadrupling the train service have reduced the cost of passenger transportation by an average of fifty percent. When the first section of consequence in the present system—from Anderson to Indianapolis—was placed in operation, the Big Four route endeavored to crush the new competition. Almost hourly trains were added to the service between these points, and the rates fixed by the traction line were met and even cut under. But it was

of no avail; passenger traffic on this division of the Big Four fell away until there remained only that of a through character. For local transport the people used the trolley line almost exclusively. After a few months the Big Four abandoned this effort at competition; and no road that since has been paralleled by a trolley has undertaken to revive it, so complete was the Big Four failure.

The effect of this is illustrated in the record made at one little town—Pendleton—twenty-six miles from Indianapolis. When the Big Four enjoyed a monopoly of transportation to and from this place, the Pendleton agent remitted from $15 000 to $20 000 from passenger ticket sales every year. Sales at the Pendleton office of the Big Four do not average more than $300.00 per month now; and, almost entirely, are for points not reachable by trolley.

Trolleys operate express trains on alternate hours, and one or two "flyer" trains make exceptional speeds. Four times daily the "Interstate Express" runs between Indianapolis and Dayton, making the trip of 109 miles in four hours and fifteen minutes. "The Marion Flyer" makes four trips each way each day, covering the seventy-two miles between Indianapolis and Marion in two hours and twenty-five minutes, while the "Fort Wayne Flyer" makes the run of 136 miles in about four hours and a half. On these trains, for which the extra-fare charge is very small, and which are as perfectly appointed as a Pullman palace car, light buffet lunches are served. Experiments are being made with sleeping cars by these trolley companies, and with the opening of the through lines a sleeping-car service will be instituted.

In the course of a few years this inter-city electric system will so web the state and beyond, that there will be small occasion for anybody to use the steam roads to transport themselves or their freight to Chicago, Louisville, Cincinnati, Columbus, Pittsburg, Cleveland, Toledo, and Detroit.

The development of freight carriage by electricity is in its infancy. Completion of the line now building from Indianapolis to the soft-coal fields of Southern Indiana will mark the beginning of an era in which the steam railroads will have to depend for tonnage originating in Indiana, upon consignments to points far beyond the state boundaries.

Investors in these traction lines have ample security, and the earnings are so large that dividend payments are generous, while six percent interest charges upon bonds are met without difficulty.

# A GRAPHIC CALCULATOR

## FOR FINDING POWER-FACTOR IMPROVEMENT BY USE OF SYNCHRONOUS MOTORS

CHARLES I. YOUNG

THE article by Mr. William Nesbit on "Synchronous Motors for Improving Power-Factor", in the August issue of the JOURNAL outlines a method of determining the characteristics of a synchronous motor required to raise the power-factor of a given k.v.a. load from its original value to a higher value. Mr. Nesbit's article has suggested the graphic calculator which is described below.

Since it is seldom practicable to obtain just the desired combination of rated motor capacity and actual load that has been calculated for a given case, the questions then are:—What will be the effect of the combination that can be secured on the k.v.a. output of the generator, and on the power-factor? And, what will be the effect if the load on the synchronous motor varies?

The method employed is a very simple one. Generator output may be represented by a right-angle triangle, of which the hypothenuse is proportional to the total current, or total k.v.a., and the base is proportional to the current in phase with the e.m.f., or the true kw. The other side of the triangle is proportional to the wattless component of the current. Likewise, a triangle may represent the input supplied to the regular load and another triangle may represent the input supplied to the synchronous motor. The triangle representing the generator output becomes, therefore, the sum or resultant of the other two triangles. The graphic method here proposed presents a ready means of showing the relation between the three triangles. The base lines of all three triangles represent true energy. The base line of the triangle representing the generator output will obviously be equal to the sum of the corresponding sides of the other two triangles, as the true energy output of the generator is divided into two parts.

If the current taken by the regular load is a lagging current and that taken by the synchronous motor is a leading current, then the 90-degree or wattless components of the currents to the load and to the motor are in opposite directions. Hence, the 90-degree or wattless component of the generator current is not the sum but the difference of the corresponding currents to the load and to the

motor, i. e., the vertical side of the triangle representing the generator output is equal to the difference between the corresponding sides of the other two triangles. If these general principles are kept in mind, it becomes a simple matter to determine the resulting relations when certain conditions are given.

Referring to Fig. 1, *AB* is taken at 100 percent to represent the k.v.a. output of a generator. The power-factor is shown as having a value of 60 percent; the true kw is represented by *AC* equal to 60 percent of *AB*, and the wattless component is shown by *BC* having a value of 80 percent. It is desired to increase the

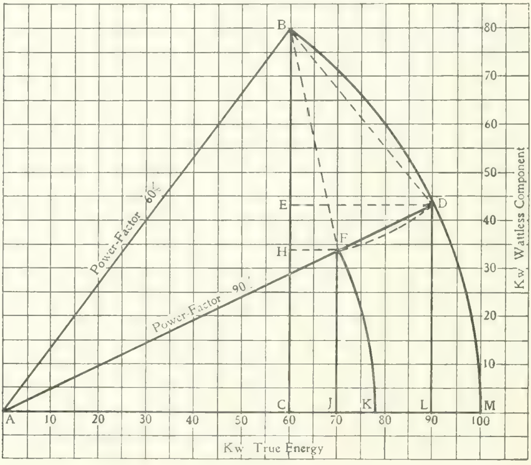



FIG. 1

power-factor to 90 percent so that the k.v.a. of the generator shall be represented in direction by the line *AD*, its amount remaining 100 percent. To raise the power-factor to 90 percent it will be necessary to increase the true energy from 60 to 90. The synchronous motor must therefore take a true energy load equal to 30, which will include the losses in the motor itself. The characteristics of the synchronous motor will therefore be represented by the triangle *BED* where the true energy is $ED = CL = 30$, the wattless component is $BC - EC = BE$ $(80 - 43.5 = 36.5)$ and the line *BD* $(= 47.2)$ represents in amount the k.v.a. input to the synchronous

motor. As it stands the diagram shows that with an input of 47.2 and a load of 30 at the motor, including its losses, the power-factor of a circuit whose k.v.a. remains constant at 100 will be increased from 60 to 90 percent.

If a true load of 30 is not to be had and the synchronous motor receives the same input as before, what will be the effect on the circuit? With $B$ for a centre and $BD$ for a radius draw the arc $DF$. The triangle $BHF$ represents the characteristics of the same synchronous motor as above with a lighter load and illustrates the effect produced by it. The input at the motor is $BF=BD=47.2$ as before. The load including motor losses is $HF=CJ=10$. The wattless component is $BC-HC=BH$ $(80-34=46)$. Thus the power-factor of the system has been increased from 60 to 90 percent as in the former case, but the generator k.v.a. has been reduced from $AD$ to $AF=AK$ or 78.

If, instead of keeping the total input of the motor constant, the 90-degree or wattless component be kept constant when the true load is made less than 30 (i.e., in practice, by increasing the compensating effect of the motor by strengthening its field), then the triangle representing the motor will consist of $BE$ as one side, and the base will be along the line $ED$, with the length measured from $E$ proportional to the true energy required by the motor. The resulting power-factor of the generator will then be less than 90 percent.

### METHOD OF USING CHART

A good perspective of any set of conditions can be obtained by using the graphic calculator shown in Fig. 2. Here as before the figures are given in percent of the original k.v.a. output of the generator (i. e., the input supplied to the regular load) which is taken at 100 percent. The calculator consists simply of a number of circular arcs corresponding to k.v.a. generator output from 100 down to 40 percent in five-percent steps. Radii are drawn to the 100 percent arc showing the lag angles which are indicated by the power-factor or cosine of the lag angle. The wattless component, which is the sine of the lag angle, can be read from the vertical scale and the true energy from the horizontal scale.

The following example will show the application of the calculator: Given 800 k.v.a. generator output at 70 percent power-factor, represented graphically in Fig. 3 by the right-angle triangle $ABC$. It is desired to increase the power-factor to 90 percent.

There is 150 hp available for load on a synchronous motor. Allowing for ten percent losses in the motor, this will mean about 165 hp or 125 kw true energy at the motor which is 15.6 percent of 800.

| | | |
|---|---|---|
| True energy of generator was originally | 70 | percent |
| True energy to synchronous motor..... | 15.6 | " |
| True energy final output of generator.. | 85.6 | " |

The ordinate erected at 85.6 (*LD*, Fig. 3) intersects the line for 90 percent power-factor at *D*, the point corresponding to 41.4

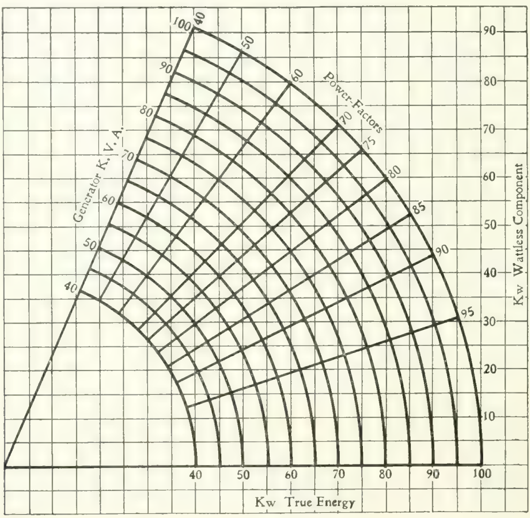



FIG. 2

wattless component. The wattless component for 70 percent power-factor is *CB*=71.4 percent. Therefore the wattless component of the synchronous motor is represented by *EB*, Fig. 3 (equals 71.4—41.4=30 percent). The k.v.a. of the synchronous motor will be *BD*, the vector sum of *BE* and *ED* (i. e., 15.6 and 30) which is 34, and 34 percent of 800 is 272 k.v.a., the required size of synchronous motor.

The intersection of *LD*, the ordinate erected at 85.6, with the 90 percent power-factor line occurs at the circular arc correspond-

ing to 95 percent generator k.v.a. Therefore a 272 k.v.a. synchronous motor with a 150 hp load will increase the power-factor of the circuit from 70 to 90 percent and at the same time will reduce the k.v.a. output of the generator by five percent or from 800 to 760 k.v.a.

To determine the effect of variations in motor load on the power-factor of the system and the k.v.a. of the generator, with a constant k.v.a. motor input, take *B*, the intersection of the 70 percent power-factor line with the 100 percent arc for a centre and, with a radius *BD* equal to the distance from this point to the intersection

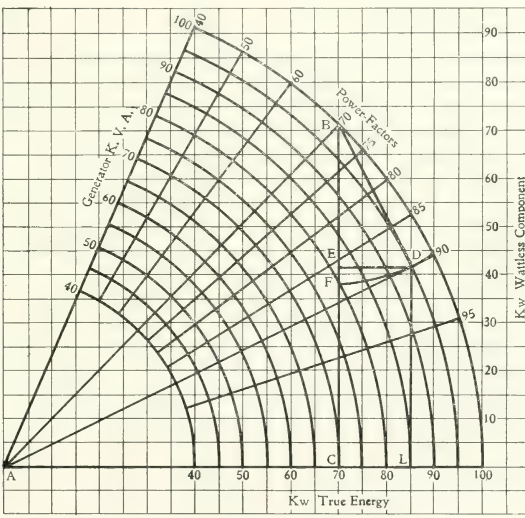



FIG 3

of the ordinate on 85.6 with the 90 percent power-factor line (this distance representing synchronous motor input), describe an arc *DF*, similar to the arc *DF* in Fig. 1. The length of the varying line *DE* would represent the varying load component of the motor and the position of the point *D* on the arc would determine the position and length of the radial line *AD*, thereby showing the values of the power-factor and the generator k.v.a. respectively.

If instead of maintaining the motor k.v.a. constant while its load varies, the wattless component is maintained constant then the

position of the point $D$ would vary along the line $ED$ instead of along the arc $DF$.

This method may be employed for determining the effect of a synchronous converter in the adjustment of power-factor. In this case the direct-current load takes the place of the mechanical load on the synchronous motor in the foregoing examples.

It should be remembered that the size of a synchronous motor or generator is determined not by its kw output but by its k.v.a. capacity; that is to say a synchronous motor to deliver only 100 kw true energy with 400 k.v.a. input would have to be built on a much larger frame than would be necessary if it were to be used for operating on a higher power-factor. A motor built on a 100 kw frame could not be given 400 k.v.a. input without burning it out in short order. Reducing the generator k.v.a. output below its original value, as shown in the example represented by Fig. 3, is seen to be equivalent to an increase in generator capacity. In considering applications of synchronous motors as outlined above, there are two extremes: On the one hand, a relatively large synchronous motor carrying a small load; on the other hand, a load in true kw equivalent to the capacity of the motor, in which case the wattless component of the motor would be zero and its effect in raising the power-factor would not be much better than an equal load in incandescent lamps, or even an induction motor at full-load.

It must be borne in mind that the power-factor of the current as well as the k.v.a. is an element that should be taken into account in determining the size of an alternator or synchronous motor. It is well known that a larger field current is required when the power-factor is low. Hence in the final determination of the size of machine necessary for a given k.v.a. rating it is essential that there be some understanding as to the power-factor at which it is to operate.

# THE ENGINEERING SCHOOL AND THE ELECTRIC MANUFACTURING COMPANY

CHAS. F. SCOTT

THE notable point of contact between the engineering school and the electric company is the engineering graduate. He is the product of the school and the raw material which is to enter into the human organization underlying the electric industry. What, then, constitutes the ideal graduate? What is expected of him and what training will best enable him to meet the requirements and the opportunities which will confront him?

The attitude of both the school and the manufacturing company toward the graduate have changed greatly. Engineering laboratories and new methods of instruction show that the schools are active and alert in appreciating the new needs. On the other hand, the manufacturing companies do not repulse the efforts of the technical man to find a job, nor do they expect the graduate to be a ready-made engineer. They provide systematic courses for supplemental training, to which they welcome college men. Probably in no other field has there been such a growing demand for engineering graduates as in the electrical profession. This demand has been a great stimulus to engineering education and it puts to a severe test the efficiency of the schools which are to furnish these men.

What, then, are the departments of work for which college men are wanted? The popular answer a few years ago was—for inventing and designing. Such an answer to-day is wholly inadequate. There is scarcely a department in the large companies, whose forces number tens of thousands of men and whose business aggregates millions of dollars per month, in which there is not opportunity for the man with engineering training. The principal fields of work are the design and development of apparatus, the testing both of commercial and of new or experimental apparatus, investigations regarding materials and manufacturing processes, the inspection of materials and apparatus, the installation and erection of apparatus on the customer's premises, conducting office work and correspondence between the works and the customer, which usually requires a broad engineering knowledge and good business ability; commercial engineering, or the specific application of apparatus; selling, and the various positions requiring executive ability, preferably with a knowledge of engineering matters. It is primarily to secure the personnel

for the rank and file and for the leadership in these various departments that the company provides a large number of college men in a training course from which it may draw. It also furnishes men for various operating and engineering positions. This course, moreover, has not been established for sentimental reasons, simply as a part of an ideal educational system, but as a matter of necessity. The men need this experience and training and the new point of view which it gives before they are useful, and the company adopts this means of getting its supply of men.

I have interviewed a number of my associates in different departments, proposing questions substanially as follows:—What are the deficiencies in college graduates? What is it that prevents the success of many of them? And what could be done in the technical school to obviate these faults?

The first reply that one man made was:—"There are as many answers as there are apprentices." While the replies which have been given to me vary in particulars, in certain features they agree. First of all, one thing is emphasized by its absence. No one has mentioned any lack of theoretical or technical knowledge. Only one man mentioned this point and he said that the schools give the men more theoretical equipment than they need. On the other hand, all agree that there is a deficiency in other things. One says that there is a general mediocrity and lack of ability to do large things; another, that there is a lack of initiative and ability to carry a thing through independently; another that the faculty of attending to details is not developed; another says that the lack of diplomacy and facility in getting along with other people is a leading fault; and another that most men do not take a real interest and are not willing to stay with one thing long enough to really get something out of it, but are continually wanting something different as soon as the novelty has worn off. Most of the men are in two great a hurry. Several referred to instances in which young men have declined to take minor work, although their superiors had a succession of positions which were to follow successful performances. It was inexpedient to explain these plans to the young men. In fact their failure to undertake and do the little things well, proved that they were not made of the right kind of stuff.

Suggestions were made with regard to college work by several of those with whom I talked. Students should be thrown more upon their own responsibility. They should be trained in making free-

hand sketches, which cultivates observation and ability to see details. Engineering students usually hate rhetoricals and language courses. They should remember that engineers are sometimes called upon to fill positions which are worth more than $75.00 per month and that in such positions they will need to know how to speak and write the English language. Students should see things from the practical rather than the theoretical or academic point of view. They should get into actual work during vacations or by devoting a year or two to practical work before completing their college course. They should be given the commercial or business point of view. Professors should be practical men. Engineering courses should discriminate between men who will take up pure engineering and those who will follow commercial work, the latter being given more of the allied and practical sciences and less theoretical training in mathematics, design and the like.

One of the gentlemen with whom I talked has had an exceptionally wide experience with young men and gave his views substantially as follows:—"Graduates are not 'handy' men, they are not apt in doing things. They are students, but are without originality or initiative. Mr. A. was an exception. When he was in the test room and was told what was wanted, he was able to devise his own methods for finding out the facts necessary to prove or disprove the point in question. Mr. B. and Mr. C. were good men on experimental work. They knew how to hang on, to think independently and to go and do things. Mr. D. was an able man on the installation of new apparatus outside of the factory. He was capable of taking up a new and difficult problem and settling it. Such were the early characteristics of four men who have now attained prominence. What is wanted is the faculty of being able to tackle a subject and find out something independently; independent thinkers are not tied down to books. Text books in general are based upon what has already been done. They are historical and are several years behind time. Many engineering tasks are like ordinary problems in mathematics. The solution given in the books is only one solution. There are usually others. Many who are able and willing to do things are tied down because experience or precedent sets the limits which they are unable to surpass. They cannot devise new ways. Aside from the ability to invent or devise new things, there is the faculty of accomplishing the same result in a superior manner by improved methods. Engineers should be able to recognize the conditions which exist; then to formulate the problem, and then to solve it."

Such is the gist of the views which my associates have expressed. Conversations which I have held with other men indicate that these views are not local, but are general.

Now all this sounds quite commonplace. Most of the statements suggest sentences from some Handbook for Young Men or Guide Book to Success. All my friends treated the problem as a serious one, in fact, with many the securing of able assistants was one of their most serious problems, and their statements, the summary of their experience, are easily resolved into a few time-honored platitudes. Possibly these platitudes summarize the experience of others and we now simply emphasize their truth by discovering their meaning.

In trying to generalize these various views and experiences it seemed to me that they simply presented the different phases of some general condition which should admit of a simple statement. The fundamental difficulty is lack of adaptation to new circumstances and conditions. This suggests a biological expression. The man fails to be "in correspondence with his environment." We may press the biological analogy still further, for we are simply considering one phase of development, the growth of the individual to form a part of the larger industrial and social life.

First of all, the individual must be capable of true growth. In nature things result from growth or from accretion—the animal grows, the crystal increases; one lives, the other does not; one assimilates new material which becomes a vital part of itself, the other adds new particles to the outside. Some men absorb and assimilate knowledge; others store it away in memory's pigeon holes. Some men assimilate experience—it broadens them and adds to their powers; others gain no more than the simple ability of exact repetition. Encyclopedias are useful, and so are human machines, but they lack the vital principle of growth.

A paragraph from "Natural Law in the Spiritual World" applies to Natural Law in the Engineering World:

> "As closely as possible we must follow the broad, clear lines of natural life. And there are three things especially which it is necessary for us to keep continually in view. The first is that the organism contains within itself only one-half of what is essential to life; the second is that the other half is contained in the environment; the third, that the condition of receptivity is simple union between the organism and the environment."

The first great factor is heredity. It fixes the initial capabilities. As the infant enters life with certain capabilities inherited from his

parents, so the engineering graduate enters active life with certain initial capabilities. He thus inherits from his alma mater certain acquired knowledge and habits and intellectual powers, and his capacity for future development of the powers which nature has given him are largely determined by the training which the foster mother gives.

Just as an "organism must either depend upon its environment, or be self-sufficient," so also must the graduate. In order to grow he must have environment—it is commonly called opportunity—and must be able to adapt himself to it efficiently.

"To seize continuously the opportunity of more and more perfect adjustment to better and higher conditions, to balance some inward evil and some purer influence acting from without—in a word, to make our environment at the same time it is making us—these are the secrets of well ordered, successful life." Such is the principle laid down by the biologist, and what he applies to life in general applies also to the engineer.

If I have correctly understood my associates and generalized their views and have properly applied certain biological principles, then it follows that the future usefulness of the engineering graduate is determined by the laws which underlie natural life and growth. The engineer deals with nature's materials and forces; his own development must follow natural laws. The engineer has laid the material basis for modern civilization and large achievement through co-operation; he himself must co-operate, he must be in correspondence with his environment. Various conclusions are easily drawn. If a school would develop a man and not a technical machine, it must train men to think and to do rather than to simply know. It must not only develop the individual, but it must rather train him in efficient relations to his environment. He must be able to apply his knowledge and use his powers; i. e., he must be practical. He must be trained in observation and judgment regarding his environment; i. e., he must have common sense. He must be able to think straight and to include all the premises. He must be able to harmonize himself with the things about him; in order to act effectively, he must have originality, initiative and independence. To work effectively with those about him, whether superiors or associates or subordinates, he must understand men. Hence, his education should be one not of engineering subjects only, but should include the humanities; nor must his education be one of books alone, he should enter into active life with his fellows.

Education has concentrated its efforts too much upon the individual in the endeavor to store his mind with facts and to develop skill in intellectual gymnastics. It has neglected the qualities which insure sympathetic and efficient relationship between the man and the world about him. This is really what we mean when we say that education is too theoretical and is not practical. We do not underrate knowledge and training, but we want them to be of use. First is individual ability; second is appropriate environment; and third, and equally essential to efficient outcome, is the correspondence and continual adjustment between the two. We want men who can see the situation and fit themselves to it.

The progress of the nineteenth century rests upon engineering accomplishment; the promise of the twentieth century calls for engineering work of a higher order and a wider scope. The future engineer must be a larger man. In contact with a great environment the resources are limitless. The possibilities and the outcome depend, therefore, upon the ability of the man to harmonize himself with his environment, and the more complete and efficient this adjustment the larger and more useful the life.

# ELECTRICALLY-OPERATED SWITCHBOARDS

B. P. ROWE

IN deciding upon a system for switching and controlling the output of a generating station, the choice of switchboard apparatus is governed by several conditions. In some cases first cost is a vital consideration. In most cases continuity of service is of the highest importance. In some cases this continuity of service must be obtained regardless of cost. In all cases, the maximum degree of safety to life and property that can be obtained should be aimed at. These and other considerations, such as space available, voltage and capacity of plant, require some study in order to secure a proper selection of switchboard equipment.

Electrically-operated switchboard equipments have been brought to such a stage of development that they may be quickly and easily handled, they are positive in their operation, substantially built and perfectly reliable. They enable the entire management of enormous quantities of power and numerous circuits to be concentrated in a small space and placed under the hand of a single operator, and enable him to be located at such a point that he can manipulate the power in perfect safety and be away from the noises and distracting incidents common to large power stations in time of accident or trouble.

There are several considerations which may exist in a proposed plant which justify the use of an electrically-operated switchboard equipment. Some of these are as follows:—

1—The voltage on the circuits may be so high that hand-operated apparatus is not obtainable, or that hand-operated air-break switching devices would require too much room in the proposed plant to permit of their installation. This condition is often met with in stations of 20 000 volts and over.

2—It may be possible by placing the switching devices and bus-bars near to the sources of current, although possibly remote from each other and from the center of control, to save enough in long and expensive conductors that would be needed in a hand-operated panel switchboard to justify electrical control from a central point.

3—It may be required that the operator shall handle great amounts of power, and for such important purposes that he must be isolated from all distracting incidents, and be at all times absolutely

safe from any personal injury from switching live circuits or from contact with live conductors.

4—The switching apparatus necessary may be too large and unwieldy to be easily handled by a manually operated switchboard. This is more frequently the case in stations with a capacity of 10 000 kw or over.

5—The number of circuits and the amount of power to be distributed may be such that without electrically-operated apparatus it could not be easily concentrated within a switchboard of reasonable and convenient size.

6—It may be absolutely necessary that the operator be located a long distance from the apparatus he controls.

### ADVANTAGES OF ELECTRICALLY-OPERATED SWITCHBOARDS

Some of the advantages of electrically-operated boards as compared with hand-operated boards are as follows:—

1—The switches used to control the potential and capacity in large stations are so large that they are more easily operated electrically than by hand.

2—Switching devices are placed in the position most convenient to the circuits to be controlled.

3—The switch gear in general can be located apart from any portions of the equipment which are liable to cause trouble in the circuits, such as steam pipes, etc.

4—For large stations it places control of the circuits in a very small space, so that the operator can have any of the circuits under his hand at any time.

5—It relieves the operator from any uncertainty in operation, or danger due to possible contact with high-tension circuits, as only low-tension wiring is brought to the center of control.

6—In case of accident to any of the apparatus the attendant is well away from the trouble and is not liable to be frightened or lose his head in an emergency.

In large central stations the control and operation of the entire equipment of large generators with their exciters, transformers and other accessories should obviously be concentrated so as to be under the hand of one central station operator, who is thus enabled to operate the station to the best advantage and with the least expense.

As the large units usually selected for such a station are necessarily installed with considerable distances between centers the usual practice of carrying the leads to a single switchboard manipulated

by hand, as formerly, will often result in placing the switchboard in a very undesirable place, if expense of conductors and facility of installation alone control the location. Moreover, the great danger involved in the handling of high-tension apparatus makes it imperative that the modern switchboard should be constructed with due consideration to the safety of the operator, which requires that there shall be no high-tension current on the operating switchboard.

### RELIABILITY OF SERVICE

When the various considerations in connection with a proposed installation have been considered, and an electrically-operated switch-

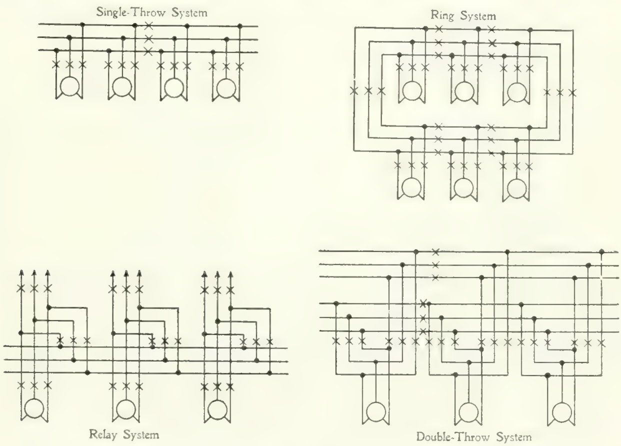



FIG. I

board decided upon, the next consideration is usually the matter of how much apparatus to install to insure reliability of service. It is possible to carry this idea to unnecessary refinements in some cases where the chances of a shut down are small and the consequences of it are not very disastrous. On the other hand, there are some plants where no expense must be spared to provide against the contingency of a shut down, even of a very short duration. The latter case involves much duplication of apparatus and great flexibility.

The simplest case is a straight single bus-bar system. This can be made more flexible by dividing up the single set of bus-bars into sections by sectionalizing switches, as shown by the diagram of the

*Single-Throw System* in Fig. 1. Where still greater flexibility is required, the bus-bars may be connected up in the form of a *Ring System*, as shown in Fig. 1; or the *Relay System*, as shown in Fig. 1, may be used, and each single generator connected to its own feeder, with a relay bus for emergencies; or a straight *Double-Throw System* may be provided, as shown in Fig. 1. Any of the systems above mentioned may be rendered more flexible by the use of sectionalizing switches. Except in special cases, it will be found that where a system is needed which will provide flexibility a straight double-throw system will be the most satisfactory.

As the bus-bars form the vital part of the whole system, it is necessary that great care be taken to install them so that short-circuits shall be impossible and that trouble on one set shall not communicate to another. When oil circuit breakers are used, it is considered the best practice to provide disconnecting switches to cut off each oil circuit breaker from the bus-bars. This permits a disabled switch to be isolated and repaired without shutting down the system.

When oil switches were first put on the market, the question of the reliability of the oil switch was a matter of much speculation, and in the most important plants, two switches were connected in series on each generator and in addition two switches were used on each feeder, so that in case of failure of one switch to open the circuit, the other switch could be opened. In some specially important cases this is still done, for the sake of being provided for any emergency, but with the reliable makes of oil circuit breakers now on the market, this practice is generally considered an unnecessary refinement.

When a large number of feeders are used, a circuit breaker is sometimes provided to connect between a certain group of feeders and the bus-bars, and is known as a group circuit breaker. Each feeder circuit of the group has its own individual circuit breaker to open automatically and relieve the group on an overload, but in an emergency, the whole group can be switched on or off the circuit by means of the group circuit breaker. The value of this group circuit breaker for a single-throw system is doubtful except in special cases when transfers of loads must be very rapid and large numbers of feeders are installed; and it is more valuable in such a case on a double-throw system because it enables transfers from one set of bus-bars to the others to be made very rapidly and with a minimum number of switches, as one pair of circuit breakers will transfer a

whole group of feeders instead of having two circuit breakers for each feeder circuit.

Where absolute certainty must be assured against interruption of service, all conductors should be isolated from each other and all adjacent material made as fire-proof as possible. In large stations this is attained by means of masonry structures and barriers, flame-proof cables, with non-inflammable supports, and cells for all fuses, arcing apparatus and oil-insulated transformers which are so con-

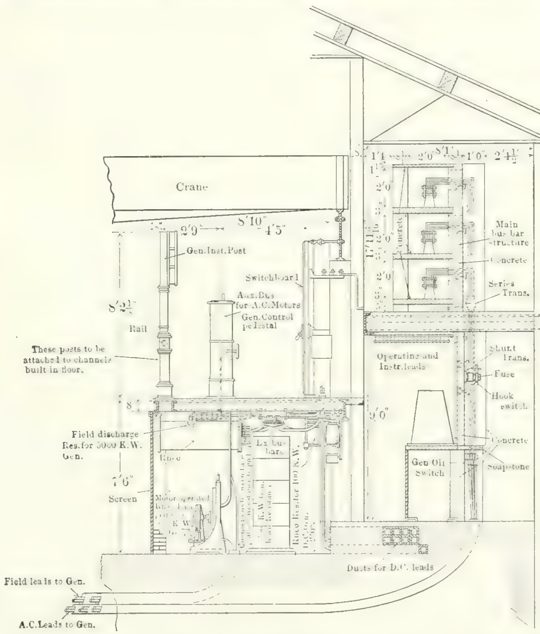



FIG. 2—HEAVY CAPACITY SWITCHBOARD FOR 2200-VOLT SERVICE

structed that there is danger from burning oil. This includes voltage transformers which are oil-insulated.

In general, the greater the amount of energy involved, the greater is the necessity for isolation, especially in plants of pressures under 45 000 volts. The isolation is most needed in heavy capacity 2 200 volt stations but is rarely advisable above 45 000 volts, as small isolated conductors well separated in air will in such cases prove

eminently satisfactory, any barriers or adjacent walls usually serving as so many grounds to insulate from. When the high-tension circuits are of very heavy ampere capacity, however, barriers may be advisable. The possibility of such condition, however, is extremely remote.

### GENERAL ARRANGEMENT OF SWITCHING DEVICES, 33 000 VOLTS OR LESS

In addition to the masonry required for the bus-bars, there must be provided structures for the oil circuit breakers. The elements are contained in structural work of brick or concrete. The concrete is becoming more popular on account of its easy adaptability to the various kinds of cell work often required. On account of this construction and the desirability of making connections between the apparatus in the safest and most direct manner, it is generally necessary to build structures in galleries one above the other. The simplest switchboards are usually double-decked, while others require three or four galleries. For a given amount of apparatus, a double-deck arrangement requires the longest galleries and more material for bus-bars. It is the simplest, however, and often the most economical when the switchboard apparatus is located near the generators and transformers, and saves long and expensive lines of connecting cables. On the other hand, where the galleries must be small, a three-deck arrangement is more satisfactory. In installations of this nature the voltage transformers are connected to large sources of power and it becomes necessary to avoid possible damage to the system by one of them burning out. It is therefore customary to protect them with enclosed fuses, the fuse and transformer being isolated in their own individual cell in keeping with the practice of isolation which has been described.

### BUS-BARS AND BUS-BAR STRUCTURES

All large stations should be laid out with a suitable arrangement of bus-bars, to guard against interruption of service from unforseen causes and to provide a means whereby circuits can be installed and connected with facility. The modern bus-bar structure for 2 200 volts and over is of brick or concrete with each bus-bar of opposite potential in its own separate compartment, well supported on porcelain insulators. The shelves or barriers in such a structure are usually of soapstone or concrete. Some of these structures are enclosed entirely, one side having removable doors, while others are made with the entire side open for inspection and facility in making

connections and alterations. As the bus-bars are well protected they are usually composed of bare copper.

In Fig. 2 is shown a typical structure for use with heavy 2 200-volt service. The bus-bar supports shown are of very heavy porcelain and capable of sustaining heavy bus-bars. The connections to such a set of bus-bars may be made either by means of cables solder-

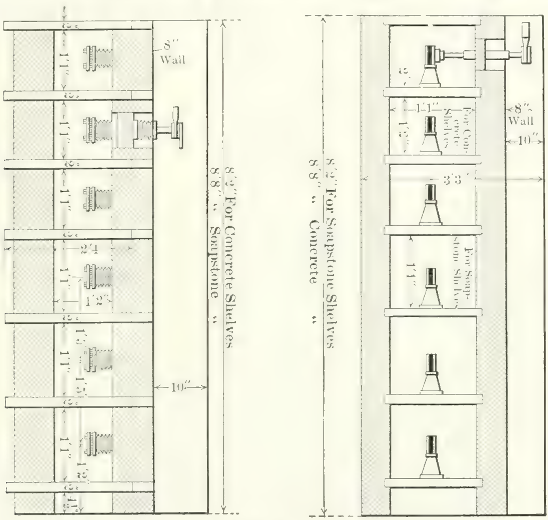



FIG. 3

On the left bus-bar structure for medium capacity, 6 600-volt service.

On the right bus-bar structure for heavy capacity, 6 600-volt service.

ed into clamp terminals secured to the bus-bars, or by means of copper straps.

In Fig. 3 is shown a suitable structure for installations up to and including 15 000 volts. The supports shown are strong enough for any bus-bars in regular use and are secured to the structure by a cement joint. The connections to the bus-bars may be made through the supports with suitable insulation for the service.

For voltages higher than 33 000 a different form of bus-bar support is generally used, and the connections to the bus-bars are made with wire or cable well supported on suitable insulators as shown in Fig. 4.

When a double set of bus-bars is to be installed, a second struc-

ture can be located back of the first one with a passage of sufficient size between them to permit of ready inspection.

The series and voltage transformers for the operation of the oil circuit breakers, meters, etc., are in almost every case placed in the structure, the best arrangement depending on local conditions. In each particular case the conditions of space, accessibility, etc., must determine the most suitable place for the structure and the best relative arrangement of the circuit breakers and bus-bars. It is customary to place each bus-bar in a separate fire-proof structure, and each pole of the oil circuit breaker in an independent fire-proof compartment. Masonry barriers separate the leads from the oil circuit breakers to the bus-bars and to the outgoing lines. Whenever it is desirable to use disconnecting switches between the circuit breakers and the bus-bars or circuit breakers and the outgoing lines on circuits not exceeding 13 000 volts, these disconnecting switches can be mounted as shown in Fig. 5, which also illustrates one of the many ways of arranging electrically operated oil circuit breakers and bus bars in two galleries.

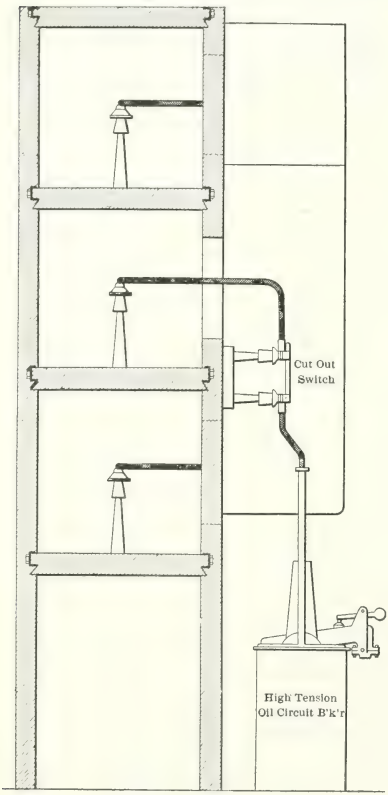


FIG. 4—HIGH TENSION BUS-BAR STRUCTURE FOR 45000 VOLT SERVICE AND ABOVE

*Cells for Voltage Transformers and Fuses*—Cells for use with voltage transformers and fuses are shown in outline in Fig. 6. The dimensions of cells for this purpose depend upon the apparatus to be installed, but for voltages of 6 600 to 22 000 volts the dimensions shown in the illustration will give an idea of the space required. When the fuses are installed in this manner, it is often desirable to close the cells with doors.

### ISOLATION OF CONDUCTORS

The enormous amount of power that is handled by a large station makes the switching of high-tension circuits a serious problem and short-circuits a cause of great danger when they occur between the switchboard connections of a high-tension station. These considerations and the necessity for getting the switchboard apparatus and connections into as reasonable a space as possible have led to the present practice, in many of the best designed high-tension stations, of isolating all high-tension conductors of opposite polarity. When barriers are used, each conductor is confined to its own compartment and in case of accidental ground or short-circuit the flashing or combustion is confined to the conductor involved and prevents the destruction of neighboring conductors.

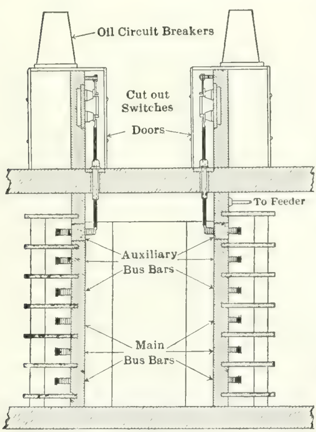
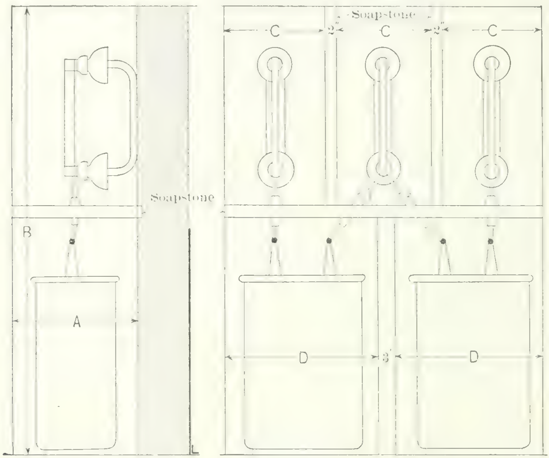



FIG. 5—DOUBLE DECK OIL CIRCUIT BREAKER AND BUS-BAR STRUCTURE
Two sets of main bus-bars and two sets of auxiliary bus-bars.

Barriers, while fire-proof, are not necessarily made of insulating material, although, were it not for the expense, they might well be made of such material. They are frequently made of brick, masonry, concrete or tile, while in places where insulated barriers are desired, soapstone is the most favored material. It absorbs less moisture than marble, but the insulating properties cannot be depended upon. The cost is a little less. Soapstone is readily obtained in any reasonable size or shape, and is easily drilled and cut when fitting is necessary

at the place of erection. When the barriers and compartments of the switchboard structure are made from any of the above mentioned materials, they should be treated as grounds with reference to high-tension circuits. It is true that vitrified brick and concrete, when very dry, are more in the nature of insulators than conductors, but the tendency of all such materials, and even soapstone, is to absorb




| Voltage | A | B | C | D |
|---|---|---|---|---|
| 6 600 | 18″ | 4′9″ | 11″ | 17 ″ |
| 15 000 | 20″ | 6′7″ | 16″ | 24½″ |
| 22 000 | 28″ | 8′5″ | 26″ | 39½″ |

FIG. 6

more or less moisture, thus preventing any absolute dependence being placed upon them as insulators, and all conductors are therefore insulated from them.

HIGH-TENSION CONDUCTORS

Manufacturers supply rubber-insulated cables, for use up to a certain voltage, which can be relied upon for a long time in regard to insulation; but it is a well-known fact that rubber deteriorates

with age and the higher the voltage the faster the deterioration; so it is the best practice in all high-tension installations not to depend upon the rubber insulation but to support the conducting cables on porcelain insulators and keep them away from all grounds and other conductors. The insulation on the cable serves, under such conditions, only as a possible preventive of troubles due to accidental contact therewith. This does not mean that the insulation is useless, as it might at times prevent loss of life or serious troubles due to accidental contact. Isolated cables laid against the grounded structure are subjected to strains, which may sooner or later break down the insulation.

FIG. 7—POST WITH NINE INSTRUMENTS

The three ammeters at the bottom are for a bank of transformers. The six instruments above are for one generator. The plug switches in the base permit testing the calibration of the instruments without removal.

Lead-covered, paper-insulated cables are seldom used in high-tension switchboard structures. Some of the best cables obtainable are insulated with rubber. As the rubber, however, is combustible and easily takes fire from flash, manufacturers supply cables, when required, covered with fire-proof braid of asbestos or with the outer braid saturated with a fire-proof paint to prevent accidental burning of the rubber cover. For extremely high voltages, cables insulated with wrappings of impregnated cambric may be obtained, with or without a flame-proof covering.

When cables with flame-proof coverings are used they must in every case be supported on insulators and not carried in ducts, as the

flame proofing is a poor insulator and when saturated with moisture will serve as a conductor. For the same reason the covering must be stripped away from all live terminals a suitable distance for insulation purposes.

The terminals of cables used in the construction of high-tension switchboards can be insulated with any good material such as oiled linen coated with shellac, but this should not be relied upon to prevent accidental contact with live terminals and no attempt should be made to insulate for safe handling, as the only time to safely handle a high-tension cable is when it is absolutely dead.

### INSTRUMENT POSTS

The instrument posts used with desks or control pedestals are divided into two general classes, viz.—swivel type and stationary type. These again may be designed with suitable bases to mount jacks, or receptacles, so that the meters may be calibrated or checked up by comparison with standards whose terminals have plugs to fit the receptacles.

The instrument posts may be specially designed to suit various numbers of meters, but there is such a large number of types available that this is rarely necessary.

A post supplied with receptacles for calibrating meters as described above is shown in Fig. 7.

*(To be continued.)*

# RAILWAY SIGNALING--IX

## THE LANGUAGE OF FIXED SIGNALS

W. E. FOSTER

THE previous articles on signaling, which have been published in this series, have dealt with the principles and with the actual details of the apparatus used in operating the various forms of signal apparatus. To the railway employes, to the passengers and to the causual observer, the signal indications themselves are the important features of a signal system. The actual mechanisms used to accomplish the desired results are not of especial interest so long as they give the positive indications desired relative to the condition of the tracks and positions of trains. Two sets of signals are commonly used, one for day and one for night service. The semaphore arm, in various positions, is used in the daytime and a light, provided with a number of spectacles or lenses, is used at night. The semaphore signal is primarily a position signal, yet in many systems the shape and color of the signal blade must also be considered in order to properly interpret the various indications displayed.

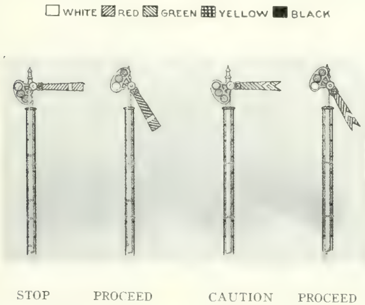



FIG. I—ONE-ARM, HIGH, TWO-POSITION INTERLOCKED TRACK SIGNALS

MEANINGS

*Home Signal.*

*Stop*—Remain stopped; route is not ready for train to proceed.

*Proceed*—Route is ready for train to proceed.

*Distant Signal*

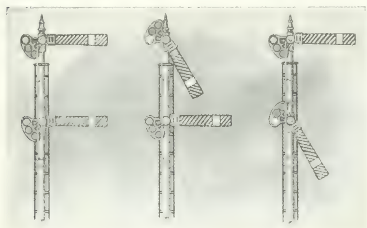
*Caution*—Prepare to stop at next home signal.

*Proceed*—Expect to find next home signal in proceed position.

The oldest and most common types of interlocked track signals are shown in Fig. 1. The two semaphore arms on the left have square ends and are painted red with a white band near the end. The night indications show a red light when the the blade is horizontal and a white light when the blade is inclined.

The semaphore arms on the right are called distant signals and have notched ends. They are painted green with a white V-shaped band near the end. At night, with the blade horizontal, a green light would appear and with the blade inclined a white light.

For many years red and green have been used on railroads to indicate danger and caution, yet on most roads they still paint their signal blades these colors and then educate their trainmen so that they understand that it is the position of the blade and not its color which really counts.



STOP PROCEED "A" PROCEED "B"

FIG. 2—TWO-ARM, HIGH, TWO-POSITION INTERLOCKED HOME TRACK SIGNALS

MEANINGS

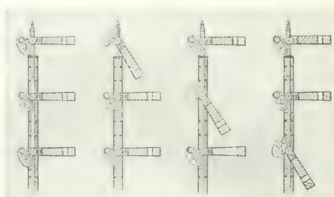
*Stop*—Remain stopped; no routes ready for train to proceed.

*Proceed "A"*—Superior route is ready for train to proceed.

*Proceed "B"*—One inferior route is ready for train to proceed.

If only two positions are used, it is evident that in the case of the distant signal, the blade must be painted a different color or have a different shape, or both, in order that its day indications may be distinguished from those of the home signal.

The home signal shown in Fig. 1 would be used only to govern movements over a track having no facing point switches for diverging routes, but this track may have one or more derails or trailing switches, which must be properly set and locked before the signal can be cleared.



STOP PROCEED "A" PROCEED "B" PROCEED "C"

FIG. 3—THREE-ARM, HIGH, TWO-POSITION INTERLOCKED HOME TRACK SIGNALS

MEANINGS

*Stop*—Remain stopped; no routes ready for train to proceed.

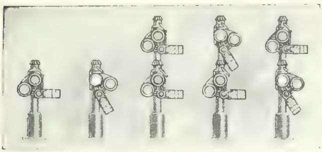
*Proceed "A"*—Main route is ready for train to proceed.

*Proceed "B"*—Second main route is ready for train to proceed.

*Proceed* "C"—One inferior route is ready for train to proceed.

In Fig. 2 are shown two-arm high, two-position interlocked home track signals. The blades are all painted red with a white band, and the night indications are either red or white, depending on whether the blades are horizontal or inclined. These signals are used where there is one superior or main route and two or more inferior or branch routes. The lower arms govern movements to any of the inferior routes. Many roads never

use more than two arms on any post, although there may be more than one superior route. Some roads always place two arms on one post although there may be no diverging routes. This is done for uniformity and in this case the lower arm would be immovable.



STOP "A" PROCEED "A" STOP "B" PROCEED "B" PROCEED "C"

FIG. 4—ONE- AND TWO-ARM, TWO-POSITION DWARF INTERLOCKED HOME TRACK SIGNALS

MEANINGS

*Stop*—Remain stopped; route is not ready for train to proceed.

*Proceed "A"*—Route is ready for train to proceed.

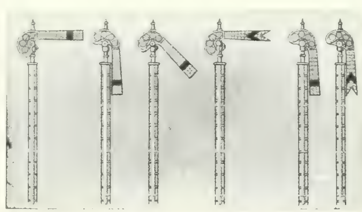
*Stop "B"*—Remain stopped; no routes are ready for train to proceed.

*Proceed "B"*—Superior route is ready for train to proceed.

*Proceed "C"*—One inferior route is ready for train to proceed.

In Fig. 3 are shown the indications obtainable by the use of three-arm two-position interlocked home track signals. The blades are all painted red with white bands, and the night indications are either red or white. This arrangement of signals should be employed only at the junctions of two main and one or more inferior routes. The use of this type of signal is constantly becoming less frequent, and the necessity for its use is met by another development to be described later.

Dwarf track signals are used on main tracks to govern movements against the regular direction of traffic and on other tracks to govern all movements. The different indications of one and two-arm two-position dwarf signals are shown in Fig. 4. The blades are red with a white band and the night indications either red or white. Since all dwarf signals govern movements which should be made at low speed, the two-arm type is very seldom used. However, track conditions sometimes require their use in



STOP PROCEED CAUTION PROCEED

HOME SIGNAL DISTANT SIGNALS

FIG. 5—ONE-ARM, HIGH, 90 DEGREE TRAVEL, TWO-POSITION INTERLOCKED TRACK SIGNALS

MEANINGS

*Home Signal*

*Stop*—Remain stopped; route is not ready for train to proceed.

*Proceed*—Route is ready for train to proceed.

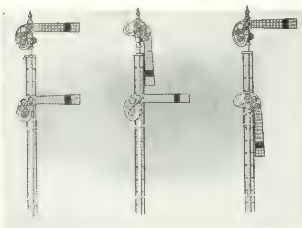
*Distant signals*

*Caution*—Prepare to stop at next home signal.

*Proceed*—Expect to find next home signal in proceed position.

order that one arm may be used to govern one particular important route only.

The signals shown in Fig. 5 are the equivalent of those shown in Fig. 1, the only difference being that the sweep of the arm is 90 degrees instead of 60 degrees, and the blades are painted a neutral color, such as yellow. Two types of distant signals have been used as shown. The distant blade with the square end was the first consistent development of the practice of giving both home and distant signal indications distinctly without any regard to color or shape of blade.



STOP PROCEED "A" PROCEED "B"

FIG. 6—TWO-ARM, HIGH, 90 DEGREE TRAVEL, TWO-POSITION INTERLOCKED HOME TRACK SIGNALS

MEANINGS

*Stop*—Remain stopped; no routes are ready for train to proceed.

*Proceed "A"*—Superior route is ready for train to proceed.

*Proceed "B"*—One inferior route is ready for train to proceed.

The types of signals shown in Fig. 6 are the equivalent of those shown in Fig. 2, the only difference being in the sweep of the arms and the color of the blades.

All of the signals just described indicate only the condition of the tracks as far as the position of interlocked switches and derails is concerned. They do not indicate the presence of trains or whether the interlocked cross-overs and turn-outs are so constructed that the movements over them can be safely made at a moderately high speed.

(*To be continued.*)

# REPORT ON ECONOMY TESTS

## 7 500 KW WESTINGHOUSE-PARSONS STEAM TURBINE

THE following data comprises the principal results obtained during the eight-hour economy test on September 1st, 1907, upon turbine No. 253, installed earlier in the year at Waterside Station No. 2, of the New York Edison Company. This test was conducted entirely by the New York Edison Company, under the direction of Mr. J. P. Sparrow, Chief Engineer. The various arrangements therefor were carried out in accordance with a mutual agreement between builder and operator entered into previous to the test, and the results were obtained by independent computation.

The turbine unit tested has a maximum rated capacity of 11 250 kw, and was built to operate on 175 lbs. steam pressure, 28 inches vacuum and 100 degrees superheat. Under these conditions, the turbine unit was guaranteed to have a minimum steam consumption of 15.9 lbs. per kw-hour at the generator terminals, with a normal speed of 750 r.p.m. Incidentally, the electrical efficiency of the generator was guaranteed to be 97.8 percent, exclusive of friction and windage, at a load corresponding to that sustained during the test. The results of the tests, detailed below, show on economy about 7.5 percent better than the guarantee.

### METHODS OF CONDUCTING THE TEST

*Load*—During the test period, No. 2 Waterside Station sustained practically all of the 25-cycle load on the system, of which the unit under test carried practically 70 percent. The remainder was carried by the other turbine units in the station. This load was maintained as constant as possible by remote control of the turbine governor by the switchboard operator. Between the first and the last hours of the test, the maximum variation in load was held within four percent above and below mean. During the last hour, however, the load decreased somewhat. Previous to the test this turbine unit had been running on a load of 7 000 kw, which was increased to its test load ten minutes before the start.

*Calibration*—Three-phase electrical load was measured by the two-wattmeter method, using two Weston indicating wattmeters of the standard laboratory type. These instruments were calibrated at the New York Electrical Testing Laboratories immediately before

and after the test. The power-factor was maintained substantially at unity, and all electrical readings were taken at one-minute intervals.

*Steam Consumption*—As a surface condenser was used in connection with this turbine unit, the water rate was determined by weighing the condensed steam delivered from the condenser hot well. This condensation was weighed in a tank mounted upon platform scales, with a reservoir above large enough to hold the condensation accumulating between each weighing as shown in Fig. 1. these weighings of 12 000 to 13 000 lbs. each, were made at intervals of five minutes.

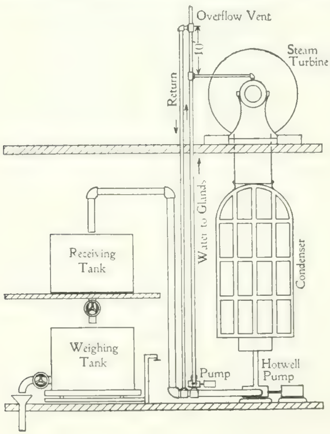


FIG. 1—METHOD OF MEASURING CONDENSATION

*Gland Leakage* — By the loop method of connecting the gland water supply, shown in Fig. 1, the necessity for correcting condensation by an amount equivalent to the weight of the gland water use, is avoided. It may be noted that a continuous gland water circuit is used entirely outside of the weighing apparatus, and that all overflow from the standpipe returns to the hot well delivery.

*Condenser Leakage* — As the circulating water is quite salt, any condenser leakage may immediately be detected by the salinity of the condensed steam, which should be pure distilled water. On this account, condenser leakage was determined entirely by chemical analysis, employing the silver-nitrate test with a suitable color indicator. This method proved extremely sensitive, and possessed a decided advantage over the ordinary method of weighing the leakage accumulating during a definite period when the condenser is idle and under full vacuum. As samples of circulating water and condensed steam could be taken at the same time, this method made it possible to discover any change in the rate of condenser leakage taking place during the test, while the methor of weighing, above described, provides only an average result during the period.

*Hot Well Correction*—In this condensing plant, the hot well pump automatically maintains the water level in the hot well at a

practically constant point, and hence no correction had to be made for difference in water level before and after the test.

*Steam Supply*—Steam pressures and temperatures were determined close to the turbine throttle. As usual, the degree of superheat was obtained by subtracting from the actual steam temperature the temperature of saturated steam at the corresponding pressure carried at the time. All gauges and thermometers were calibrated previous to the test at the U. S. Testing Bureau. It will be noted that both pressure and superheat were somewhat below the guarantee.

*Vacuum*—Vacuum was measured directly at the turbine exhaust by means of a mercury column with a barometer alongside for re-

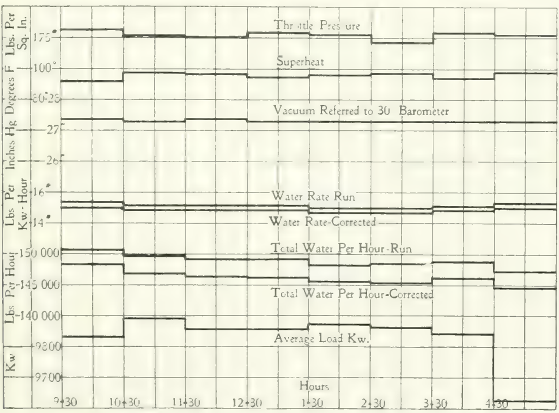



FIG. 2—HOURLY LOG OF ECONOMY TEST

ducing to standard barometer (30 inches). This also obviated the necessity for temperature correction between the two mercury columns. During the test the vacuum was not maintained quite up to normal.

## RESULTS OF TESTS

The following data represents the results of the tests, calculated for the conditions as actually run; i. e., for instrumental errors only:

| | |
|---|---|
| Duration of test | 9:30 A. M. to 5:30 P. M. |
| Average steam pressure at throttle, lbs. per sq. in. gauge | 177.5 |
| Average superheat at throttle, degree F | 95.74 |
| Average vacuum (referred to 30 in. barom.) in. Hg | 27.31 |
| Average load on generator, kw | 9830.48 |
| Average steam consumption, as tested, lbs. per kw hr | 15.15 |

*Test Correction*—Owing to the departure, during the test, from the specific operating conditions, it was necessary to correct the observed results by the following amounts:

Pressure (2.5 lbs. high) correction, 0.25 percent; vacuum (0.69 inch low) correction, 1.84 percent; superheat (4.26 degrees low) correction, 0.29 percent.

These corrections were mutually agreed upon previous to the test as representative of this type of turbine. When applied to the observed steam consumption given above, the following results, representing contract conditions, are obtained:

Average corrected water rate during 8-hour test..14.85 lbs. per kw-hr.
Guaranteed water rate............................15.9 lbs. per kw-hr.

*Log*—From Fig. 2 it may be seen that the load was lower during the first and last hour than during the main part of the test. Considering only this six-hour period from 10:30 A. M. to 4:30 P. M., the results are as follows:

Average corrected water rate, six hours............14.8 lbs. per kw-hr.
Equivalent water rate........................10.65 lbs. per brake hp-hr.

The two latter quantities are determined by applying conversion factors for generator efficiency and for internal losses.

In connection with these tests, a noteworthy agreement exists between the results noted and those previously obtained from tests of machines similar in design installed in the Manhattan Station of the Interborough Rapid Transit Company, New York, and the Long Island City Station of the Pennsylvania Railroad. At the same loads and with equivalent operating conditions, the performance of the machines is almost identical. These economic results, while not exceeding in actual steam consumption the best records of European practice, yet are extremely good in view of the moderate operating conditions under which the test was conducted. In fact they represent the best results that have yet been obtained by any turbine under the conditions named.

# EXPERIENCE ON THE ROAD

## LINING UP A NEW GENERATOR AND WATER-WHEEL

C. L. ABBOTT

THE writer had the following all-night experience recently in a power house where an old generator which was direct-connected to a water-wheel was to be replaced by a new machine. When the old generator was uncoupled from the water-wheel, it was found that the water-wheel shaft could not be stopped in the usual way owing to a leak in the gate, and it was necessary to rig up a heavy clamp made of ten-inch timbers. This was placed on the shaft and tightened up until the wheel came to a standstill. Then the new half coupling was fitted to the shaft and the key driven home. Before coupling to the new generator it was thought best to make sure that the coupling ran true. The wooden clamp was loosened enough to let the shaft turn slowly. A steel point held on a rest showed that the face of the coupling was running out of true a full thirty-second of an inch, probably due to the key being high and driven in too tightly. As it was past midnight and it was necessary that the generator be running in the morning, something had to be done without delay. The power house was on a lonely stream several miles from the nearest town, hence there was no means of getting good tools quickly. An old slide rest and lathe tool were found and mounted on wooden supports so that a cut could be taken across the face of the coupling. A man was stationed at the wooden clamp with a wrench to govern the speed, by tightening or loosening the bolts, while another poured cold water on the clamp to keep it cool.

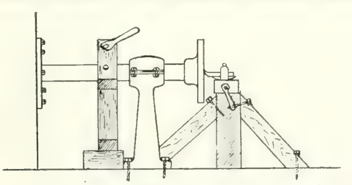


FIG. I

After the first cut was taken off it was found that the tool was too dull to make a second cut, and as there were no other tools available matters looked serious. After groping around some time with a lantern, some pieces of emery cloth were found in a tool box. These pieces were wired around the water-wheel shaft in such a manner as to leave a clear space in the middle. The wooden clamp

was again loosened, and as the shaft whirled the emery cloth around the tool was quickly ground sharp on the improvised grindstone.

Without further mishap the coupling was turned true, coupled to its mate on the generator shaft, and the machine put in operation.

As that group of grimy, tired-eyed men stood there in the gray of the morning and watched that machine running as smooth as a watch, they felt well repaid for their night of toil.

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## LOCATING AN INTERMITTENT GROUND

C. G. RALSTON

A SHORT time ago the writer was summoned to a power-plant to find the cause of one generator dropping its voltage. There were two 75 kw, 125-volt direct-current generators in this station driven by a Delaval steam turbine. The generators were connected in series to supply a 220-volt lighting system. The generators were started up and the voltage of each machine was kept as near 115 volts as possible. Everything ran smoothly for about an hour, when the voltage of one machine dropped to 90 volts and then to 80 volts and still lower for an instant, and then came up to 115 volts again. This happened several times within the next hour and lasted two or three minutes each time. The machines were then shut down and tested for grounds, as all connections were correct and with good contacts. The ground test indicated a heavy ground at one of the shunt field coils of the generator whose voltage had dropped. The pole piece and field winding were removed at once and the field re-insulated. After the pole and winding had been replaced, the machines were started up and put into service again.

The system was tested for grounds and a heavy ground was found on an iron conduit lighting circuit in an elevator shaft. This ground was located in several old lamp sockets which had been recently installed and was on the opposite side of the line from the ground on the machine, thus short-circuiting its field winding and causing the voltage to drop. The ground on the system was intermittent and occurred only when the elevators were running, which caused the conduit pipes to vibrate.

THE

# ELECTRIC JOURNAL

VOL. IV. DECEMBER, 1907 NO. 12.

**The Year's Record**

It is a custom, and a good one, with the close of a volume of such a periodical as the JOURNAL to look it over and see what it stands for; whether, on the whole, the editor has cause to be satisfied and what he can promise readers for the coming year. One who has looked over similar notices in the popular magazines must have observed that the strongest point they can bring out is the standing of the writers who have contributed and who will contribute to the publication. From such a standpoint the JOURNAL can well invite comparison with any other technical publication. An examination of the list of contributors during the past year will show that they are recognized experts in their various lines and many of them are men of international reputation, as well as being leaders in their particular branches of the profession.

Another feature which gives unusual strength to the contributors of the JOURNAL is the fact that they are almost all men who are so placed as to have had the widest and best experience. In a line of work which has been thoroughly established for many years and whose general principles have been set forth in text books and taught in the colleges for long periods, it is often possible that a writer who has the faculty of keen analysis and the accomplishment of clear exposition may write an article even better than an expert practitioner. This is not yet the case with electrical matters. So much of the work is along lines which are still new, that it is only the practitioner, who is in daily contact with the apparatus and so situated as to be able to keep in touch with its work, who is able to write articles that will be of real value.

I had this point forcibly brought to my attention some time ago when I was requested to recommend to a gentleman who is essentially a mechanical engineer a good book on the testing of electrical machinery. On going over this matter with some experts, they all agreed that the very best treatise on this subject was the series of articles which ran through the early numbers of the JOURNAL.

I have also heard in a number of cases of readers who had

gratefully acknowledged the pecuniary as well as the professional benefit of articles which have appeared. The truth is that the relation of the editor to men who are capable of contributing valuable articles is such as to place the JOURNAL in an unusually favorable position, and this holds for the future as well as the past, so that the readers of the JOURNAL may expect with confidence that the high standard of contents which has hitherto obtained will continue.

W. M. McFARLAND

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**The Grounded Neutral**

"The discussion has been inadequate. The grounding of the neutral is not a simple matter; it is fundamental. There is scarcely an element in the whole transmission system which is not in some way affected by it." This remark was made by the chief engineer of a large power transmission system at the close of the general discussion on "The Grounded Neutral" at a recent meeting of the American Institute of Electrical Engineers.

I used to regard the subject as one which particularly concerned cable protection and the adjustment of lightning arresters. Mr. Lincoln remarked that in writing the paper which opened the discussion he expected to make the presentation in a few pages, but was surprised to find how the subject enlarged as he proceeded, until the paper was of considerable length, although he made no pretensions to exhaust the subject.

Under normal conditions of line insulation and operation it is a matter of no particular consequence whether the neutral be grounded or not. It is in emergency conditions that differences result, which in some way or other affect nearly everything connected with the system. For example, first of all, the generator is involved. If its neutral point be grounded, then the grounding of one line produces a short-circuit, not, however, between the generator terminals, but between the neutral point and one terminal. The short-circuit of a part of the winding results in a greater flow of current than would exist if there were a short-circuit between the terminals. The consequence of grounding the neutral is therefore the probability of a greater number of short-circuits of a more severe character than when the neutral point is not grounded. Again, a generator has the potential between its terminals and ground held at a fixed maximum if the middle point is grounded, whereas if the neutral point is not grounded the remaining terminals are subject to a sudden increase of potential when one terminal is grounded.

Even the secondary circuits at the distributing station are affected. It was pointed out in the discussion at the Pittsburg meeting of the A. I. E. E. that the low-tension circuits of transformers act as one plate of a condenser of which the primary coils form the other plate. If the primary circuit is liable to considerable changes in its static potential with respect to the earth, then a charge appears on the secondary. If, for example, one terminal of an alternating current circuit be connected with the ground, the windings are alternately positive and negative with respect to the ground. The induced charge on the secondary introduces a potential between the circuit and earth, the amount of which depends upon various conditions, among which are the capacity and insulation resistance of the circuit.

Transformers to be used in a three-phase system with grounded neutral should have their high tension windings star-connected—hence the problem of grounding involves the relative merits of delta versus star-connection. If one terminal of a transformer in a star-connected system be grounded then the strain on insulation to ground at that terminal is zero, increasing through the windings to fifty-eight percent of the line voltage at the other terminal. If the neutral be not grounded, then in case of a ground on one of the transmission wires connected to another transformer, the potential of the central point of the star would be raised from zero to fifty-eight percent and the other terminal would be raised from fifty-eight to one hundred percent of the line voltage. The problem of grounding therefore involves transformer design as well as safety in operation.

On the one hand there is a fixed limit to the potential between the line wires and earth which is secured by the grounded neutral; on the other the potential of any line may be raised to nearly double the normal by the accidental grounding of another line. Hence the insulation of apparatus and the strength of line insulators, especially in the case of extra high voltages; the insulation of cables, which have relatively high capacity and in which surges are liable to result when potentials are suddenly varied and the adjustment of lightning arrester sparking distances, are all intimately concerned in the grounding problem.

If the neutral be grounded then a ground on one wire necessarily causes a short-circuit on a part of the system, which is obviously not the case if the neutral be insulated. Hence automatic circuit breakers and their actuating mechanisms for cutting out defective lines are materially affected by the grounding of the neutral.

If a resistance be inserted in the connection between neutral and ground the flow of current is reduced, but the potential of the neutral is not held at zero but rises in proportion to the value of the resistance and the strength of the current, which complicates the action and introduces compromises by lessening both the disadvantages and the advantages of the grounded condition. These points are elaborated in the presentation of the subject before the Institute.

Outside of the system itself its effect on other circuits is influenced by the neutral connection, both as to static induction, which is decreased by keeping the neutral point of the system at zero potential, and as to earth currents, which are liable to be greater when the neutral point is grounded.

Aside from the practical *pros* and *cons* which have arisen in the discussion of this subject, it is interesting to note the intimate interconnection and interdependence of the various elements which enter into a transmission system, both as to their design, construction and operation. There are but few apparently simple subjects whose investigation will lead to a fuller understanding of the fundamental, theoretical and practical elements which enter into the transmission system. The discussion, however, does not seem to lead to the same conclusions in all places. Some of the large underground systems in New York are operating with the grounded neutral, which is relied upon as a very important element in securing continuity of service. Another system does not employ the grounded neutral, and believes that its fullest safety and its best protection against accidents are secured by its present methods of operating. This question, therefore, must be classed among those which do not admit a yes or no answer, but are engineering problems whose solutions are often controlled by local and special conditions.

CHAS. F. SCOTT

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**A Journal Question Box**

Without any formal arrangement the JOURNAL has been receiving numerous inquiries regarding technical matters from its subscribers, to which it has endeavored to reply, either directly or through articles prepared for publication. Many of the questions and answers are of general interest beyond furnishing the information desired by the questioner. In order that all our readers may profit by the efforts of the JOURNAL to solve the many perplexing problems which are continually being presented to electrical workers, it has been decided to anticipate the co-operation of its readers and estab-

lish a regular department in the JOURNAL in the nature of an open question box. The JOURNAL, through The Electric Club, many of whose members are engineers of wide experience and high standing, has ready at hand an able corps of expert advisors who may be called on to render assistance in answering many practical problems which it would be difficult for the ordinary editorial force to solve.

The invitation is hereby extended to our subscribers to make use of this department to assist them in their work and to obtain information regarding points which will be of value to them. As in any department of this kind the topics should be of general interest and of the kind that can be treated briefly.

THE PUBLICATION COMMITTEE

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**Our Four Year Index**

Availability is one of the first requisites for stored information. A technical periodical or the transactions of a technical society are of relatively little use for reference unless accompanied by an index. The technical journal whose articles are not merely of passing interest but are of permanent value requires an index, both for the readers who know that an article on a given subject has appeared at some time in the past and for use also by those who may be in search of information and are uncertain whether or not a given article has appeared. Those who search through the ordinary annual or semi-annual indexes of technical journals appreciate the need of something better.

Most readers of the JOURNAL are familiar with the topical index which has appeared from year to year covering all previous issues of the JOURNAL. At the end of this, the fourth year, the last index is now supplemented by references to the articles which have appeared during the present year. This single index, therefore, makes all of the four volumes of the JOURNAL, aggregating nearly three thousand pages and approximately five hundred articles, immediately available.

This unique and original method of indexing has been appreciated by our readers in the past, which is the principal reason that the labor of compiling and issuing the extended index has been undertaken. A number of the early issues of the JOURNAL have been reprinted so as to make complete sets of bound volumes available for our new subscribers.

THE PUBLICATION COMMITTEE

# THE GREAT FALLS POWER PLANT OF THE SOUTHERN POWER COMPANY

L. T. PECK

THE ultimate capacity of the entire system proposed by the Southern Power Company will probably reach 200 000 kw, made up of stations of from 7 000 to 40 000 kw, distributed over parts of both Carolinas and feeding into mains covering a territory of approximately 200 by 150 miles. Their Great Falls station is located on the Catawba river about forty miles north of Columbia, South Carolina. In this vicinity for a distance of eight miles the river consists of a series of falls and shoals with a total drop of 176 feet. Sites for three plants to utilize this power have been chosen, at Fishing Creek upstream with a head of 40 feet, at Great Falls in the center with a head of 72 feet, and at Rocky Creek downstream with a head of 60 feet.

The development at Great Falls was taken up first, the work begun in November, 1905, and completed in March, 1907—with

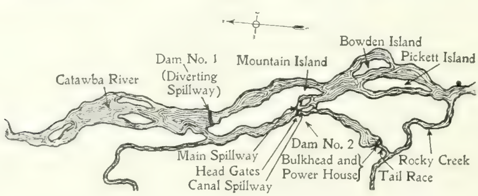


FIG. 1—MAP SHOWING RELATIVE POSITION OF POWER HOUSE, HEAD GATES AND DAMS

machinery in place and current on the lines by April 2nd. The time of construction covers the building of a standard gauge graded railroad from Fort Lawn to Great Falls, a distance of ten miles.

The power house is located, as shown in Fig 1, at the foot of a natural valley which connects with the Catawba river at a point just above the lower end of a strip of land known as Mountain Island. At the upper end of the island a spillway dam was constructed to divert the water into the western channel and at the lower end of the island a second dam turns the water through headgates built across the upper end of the natural valley (Fig. 2), the water flowing through this latter channel to the retaining bulkhead at the

power house, a distance of about a mile and a half. The relative location of the different dams, the station, etc., are shown in Fig. 1. The construction of dam No. 2 is shown in Fig 2. Its height was so calculated that it becomes a spillway when the water at the bulkhead reaches a fixed maximum, thus insuring against damage to the station from floods. This arrangement makes the valley above the power house virtually a reservoir in which the head is practically constant irrespective of the stage of water in the river. Fig. 2 also shows the retaining wall below the headgates which was the only artificial barrier necessary to confine the water to the new channel.

A good idea of the relative positions of the power plant, bulkhead, etc., may be obtained from Figs. 3 and 4. The method of

FIG. 2—VIEW OF DIVERTING DAM NO. 2, HEAD GATES AND RETAINING BARRIER

placing the feeder pipes in the bulkhead is shown in Fig. 3, as well as the power house while under construction.

The bulkhead at the power station is constructed of rock and concrete and entirely encloses the steel turbine feeders and wheel cases, the latter being supported on heavy steel I-beams. A tunnel running the length of the generator house, located directly back of the wheel cases and arching under the intake pipes, allows access to the hydraulic equipment from within the bulkhead. The flume gate mechanism at the top of the bulkhead is operated by a hoist motor located in a pilot house built above the exciter turbine feeders.

The power house is built in two sections, a generator house and a transformer house, and is finished in red pressed brick with stone trimmings and tile roof. The entire station is built over the tail

races and supported on foundations of cut limestone. The location of the various apparatus in the generator and transformer house is shown in the plan view in Fig. 5. In the transformer house the transformers and low tension switches occupy the first floor with transformers placed six on either side of the building and the switches in the center, two concrete walls dividing the space into three rooms. The high tension control and protective apparatus is located on the second floor.

The apparatus within the station is grouped electrically into four units, each composed of two generators and three transformers with accompanying control and protective apparatus and each supplying its own set of outgoing feeders. Provision has been made for operating the station under all conditions of load, the several

FIG. 3—BULKHEAD AND POWER HOUSE IN PROCESS OF CONSTRUCTION

units being so interconnected that any generator may feed into any bank of transformers and any bank be used with any of the outgoing lines.

TURBINES

The turbines are of the twin horizontal type and develop their maximum efficiency at about three-fourths gate opening corresponding to full-load on the generators. At this point the wheels develop what may be considered the normal output of the station, thus insuring a minimum loss between the wheel inlet and generator terminals under average load. The loss is little greater at overload, as the generator efficiency increases slightly, thus partly offsetting the decrease in turbine efficiency. The feeder pipes of sheet steel are elliptical in shape at the gate and gradually decrease in diameter

toward the wheel cases when they become circular. The turbines operate in pairs, each pair being controlled by an automatic governor. The draft tubes are circular at the turbines and gradually widen out to form an ellipse at the outlet.

### GENERATORS

The generators are located in a uniform line along the north side of the power station and direct-connected to their respective turbines, as shown in Figs. 5 and 6. The frames are of the cut under type movable parallel to the shaft, and a pit beneath each machine permits ready access to the lower half of the armature winding.

FIG. 4—END VIEW OF GREAT FALLS POWER HOUSE

The exciters are also turbine driven and each machine is capable of supplying the exciting current for the entire station under maximum load. They are located in the middle of the station just in front of the switchboard gallery.

### TRANSFORMERS

The twelve transformers are arranged in four banks, two on each side of the transformer room. Each transformer is in a separate concrete compartment and the base of each tank is equipped with flanged wheels, which rest upon steel rails placed at a height

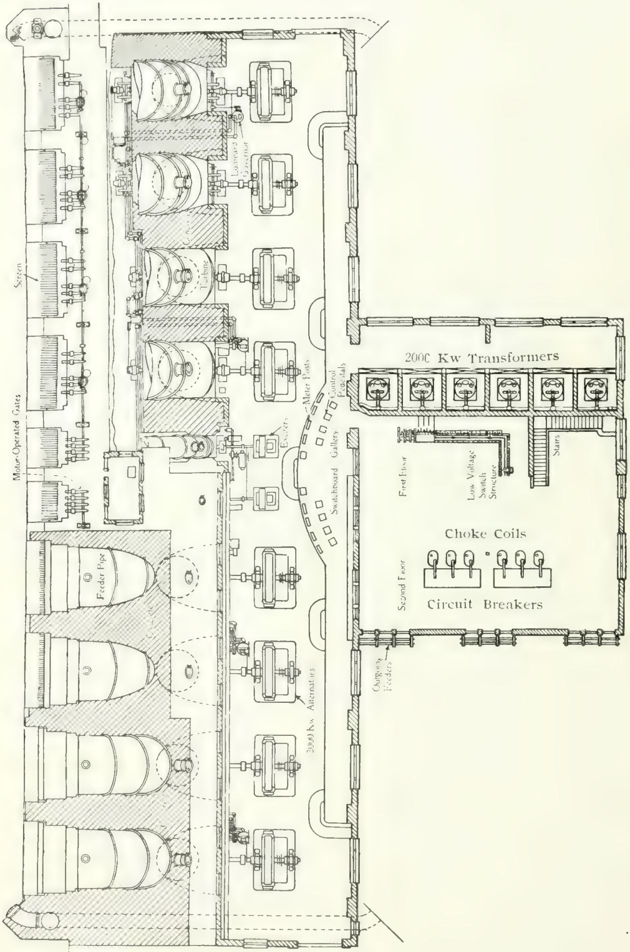


FIG. 5—PLAN OF STATION

such that the tanks can be transferred to a truck, which runs on a track the full length of the room. Each case is equipped with a thermometer placed near the top, with the bulb projecting into the oil, thus registering the temperature at all times, and should this exceed a predetermined limit, an electrical contact device sounds an alarm. This serves to protect the apparatus against excessive load on any one bank and gives warning in case of failure of the water supply.

In addition to the regular ratio of transformation from 2 200 of 44 000 volts, provision has been made for full output at 22 000

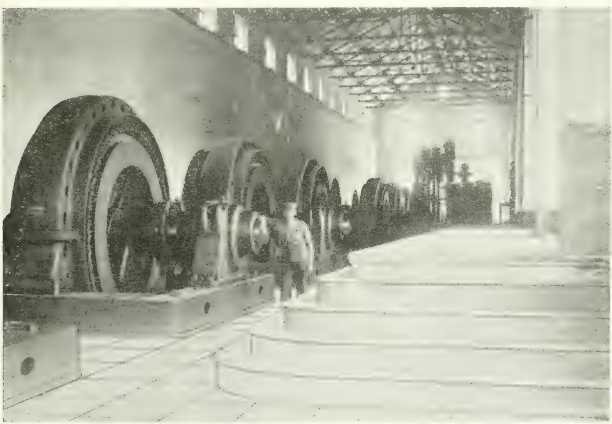

FIG. 6—INTERIOR OF GENERATOR ROOM

or 11 000 volts high tension and 1 100 or 550 volts low tension by connecting the windings in various series and parallel combinations. Taps are also arranged so that low tension voltages of 2 100, 2 000 or 1 900 volts may be obtained.

The operation of water cooled transformers necessitates the installation of a system of piping. In this case four-inch water mains are run from the exciter turbine cases at the bulkhead to the basement below the switch-room, with feeders leading to each transformer room from which individual taps are taken, the supply pipe passing under the case and up through a regulating valve to the coil inlet, located in front. The cool-

ing coils are divided into three groups, connected in parallel, which insures better radiation than would be the case were one continuous coil used. The discharge pipes empty into a funnel leading to the waste main, which empties into the tail race. The pipes leading to and from the cooling coils are provided with unions, placed so that, when uncoupled, the transformer may be moved forward onto the truck. The amount of water required at full-load to insure a temperature rise of not more than 40 degrees C. above the incoming water is four gallons per minute. With an increase in the flow of water the transformers will operate continuously at overload without abnormal temperature rise. Water for local use is also taken from the supply mains, numerous risers being carried to the first and second floors.

*Oil Supply*—A general oil supply is maintained outside the power house and fed by gravity into the piping system. Supply and discharge pipes lead from the basement to the transformer rooms and connect with individual supply and discharge leads, which enter the tanks from the side, near the top and bottom respectively. They are provided with suitable control valves and unions for rapid disconnection. Risers provided with hose bibs are run from the supply pipes of two of the transformers to the second floor to furnish oil for the high tension apparatus.

*Filtering*—Occasionally it is necessary to filter oil that is constantly in use and to accomplish this a motor-driven pump has been installed in the basement, the oil being drawn off and sent through the filter into a local reservoir and from there either returned to the tanks by reversing the pump or forced into the holder outside the building.

*Emergency System*—Each transformer case is equipped with a valve at the bottom, connecting directly with the waste main, so that in case of fire the oil may be quickly emptied into the tail race. As a further insurance against damage from this source, a complete system of piping for carbonic acid gas has been installed.

A gas generator and pressure tank is located in the basement and connected with each transformer through a feeder scheme similar to the supply systems just described except that the main is brought up into the low tension switching room and the distributing pipes branch from a common center, where each is provided with a control valve, properly numbered, enabling the operator to quickly turn gas into the burning tank.

While each case is designed to withstand the pressure exerted

by an internal explosion under operating conditions, practicaclly absolute safety is assured through the installation of a "vent" pipe connecting with the top of each transformer and carried through the end of the building. This is provided with a check valve to prevent mosture reaching the apparatus.

SWITCHING EQUIPMENT—ALTERNATING-CURRENT CIRCUITS

*Low Tension*—The scheme of generation and distribution followed is a division of the plant into four units of equal capacity, each complete in itself—if the exciters be excepted—but so interconnected that any combination of generators, transformers and feeders may be effected.

The generator leads—one per terminal—are carried through three-duct conduits into a cableway beneath the switchboard gallery. Thence they run upon shelves, built into the concrete, to the basement beneath the switching room, where they rise to the generator switches, which are mounted in a concrete structure. This structure is built around three side of the switching room with sufficient clearance between the rear and the walls to allow of easy access to the switches. The generator switches and transformer switches are located on either side with a sectionalizing or bus-junction switch, mounted in the structure at the end of the room. From the generator switches the leads are carried directly up to the 2 200 volt bus-bars, which are mounted in fire-proof concrete cells, supported by a structural steel gallery built around three sides of the room immediately above the switch structure. The concrete work of the switch structures is carried up to the gallery, thus forming continuous cable wells from switch terminal to bus-bar clamp. The disconnecting knife switches are mounted in these compartments above the generator and transformer switches.

All of the low tension switches or circuit breakers (the terms are used synonymously here), are of the three-pole, oil-immersed, electrically operated type, as shown in Fig. 7, any one of which will successfully open the circuit under any condition of overload or short circuit with the entire station back of it. The generator and bus-junction breakers are non-automatic, while those connecting with the low tension side of transformers are automatic, with overload relays actuated from the secondaries of series transformers mounted in the cable wells just described. Each pole is enclosed in a separate compartment and the unit operating mechanism is supported immediately above, on a soapstone slab covering the switches.

Each circuit breaker is closed by a solenoid energized from the exciter circuit, and opened by gravity. These features are worthy of especial note, as with this arrangement it is impossible to cut in a machine without the knowledge of the operator, and the circuit breakers will automatically open in case of failure at any part of the control circuit.

The sectionalizing knife switches make it possible to so divide the bus-bars that each transformer bank is fed from a separate section. Normally, however, four machines on either side of the junction circuit breaker will operate in parallel. This circuit breaker is electrically operated and can be opened or closed under load.

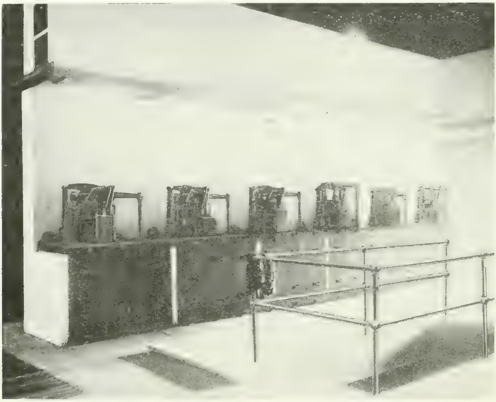

FIG. 7—LOW TENSION SWITCHES AND BUS-BAR COMPARTMENTS

The leads from the transformer switches—two per terminal—are run from the basement to the transformer rooms, through conduits in the supporting piers, the delta being made by locally cross-connecting with short lengths of cable.

*High Tension*—Sectionalizing disconnecting switches in the high tension bus-bars make it possible to feed any outgoing line from any bank of transformers, the general scheme being much the same as in the low tension room, though here the bus-bars may be cut out entirely if it is desired to connect directly from each transformer bank to its out-going feeder through the choke coils and line circuit breaker. A high tension, oil-immersed, electrically operated

bus-junction breaker performs the same function in connecting and disconnecting between buses as the low tension circuit breaker previously described.

The high tension conductors of copper tubing are covered with a formed insulating material of special compound, designed more to prevent accidental short-circuits than to insure personal safety.

The transformer and line circuit breakers are of the electrically operated, three-pole, double break type; each pole being enclosed in a rectangular boiler iron tank, lined with treated soapstone, supported upon a wooden framework. The design employed is the same as for 60 000 volt work—the insulation between terminals and to ground withstanding a break-down test of 120 000 volts. This circuit breaker is designed for use in three-phase circuits of 45 000 k. v. a. or less, and to successfully open the circuit under any condition of overload or short-circuit with a station capacity of 150 000 kw back of it. The closing mechanism is actuated by a solenoid connected to the exciter circuit, and a tripping coil, similarly connected, breaks the toggle holding the poles in the closed position, thus allowing them to open by gravity.

The transformer circuit breakers are electrically operated, but non-automatic, while those controlling the feeders are automatic, with inverse time limit relays. The series transformers which actuate these relays are connected in the out-going line; one in each outside leg. They are of the oil insulated type, mounted in cylindrical boiler iron tanks, with cast iron bases, and will operate continuously at normal current with low temperature rise. High tension disconnecting switches, located on either side of the oil circuit breakers enable the operator to completely cut out any circuit breaker which it may be necessary to examine. All of the high tension apparatus is designed to withstand an insulation test of 100 000 volts for 60 seconds.

### SWITCHING EQUIPMENT—DIRECT-CURRENT CIRCUITS

The exciter mains are carried to the cable way below the switchboard gallery and thence through double-throw switches to a double set of bus-bars located beneath the gallery bay. The field leads are carried by the same cable way to the rheostat dial plates. The generator field leads run through the cable way to their respective field rheostats and connect to the exciter bus-bars through double-throw field switches. All of the alternating and direct-cur-

rent instrument wiring and the direct-current control wiring leading from the various electrically operated switches focus in the "Rheostat Room" beneath the center of the gallery and rise to the controlling switches and instruments above.

*Station Control*—The most modern method of station control has been adopted. The switching gallery already referred to is a raised platform (See Figs. 6 and 8), extending about two-thirds the length of the generator room and describing an arc at the center, as shown in Fig. 5. Instrument posts on which the meters are mounted are arranged along the outer edge of the gallery and in front of these the control pedestals are similarly arranged, each numbered to designate the generator it controls. The advantages of this general arrangement are apparent, for not only is the danger of connecting in the wrong machine reduced to a minimum, but

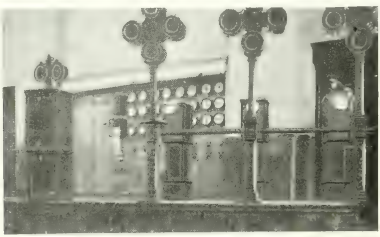

FIG. 8—SWITCHBOARD GALLERY

the operator has full view of all machines and can instantly take steps to rectify any trouble which may occur.

*Flexibility*—There are one or two interesting points in connection with the apparatus used which should be brought out, that the method of accomplishing certain results may be better understood. The two exciters may be connected to either of a double set of bus-bars, this arrangement making possible a number of generator and exciter combinations and thus increasing the flexibility of the system. A double bus-bar necessitates double-throw field switches and those installed were made up from a special design, the feature of which is the ability to tranfer from one source of excitation to the other without opening the field circuit. The switch consists essentially of two double-throw two-pole knife switches, one within the other, the adjacent blades closing into jaws common to one stud. In changing from bus A to bus B, the outer or larger switch is

thrown from the upper to the lower position, the inner or secondary switch holding the original connection during this operation, afterward following the main switch to the new position. The contact which connects the field terminals through a discharge resistance when both switches are open is attached to the inner blade.

*Field Rheostats*—Both the generator and exciter field rheostats are connected by chains and sprockets to the hand wheels, mounted on the pedestals. The use of pedestals instead of panels allows a better arrangement of rheostats in the basement, with more space and greater facility for ventilating.

*Exciter Control*—The exciter control pedestals are located on either side of the center of the platform, directly in front of the direct-current machines. The exciter circuit instruments, as well as switches, are mounted on these pedestals. Equalizer switches for parallel operation are mounted upon small individual pedestals apart from the control pedestal.

*Switchboard*—Set in an arch in the wall separating the generator and low tension switching rooms and directly behind the semicircle of pedestals and posts is the switchboard controlling the low tension and high tension sides of the transformers, the bus-junction breakers, and the outgoing feeders. By means of two graphic recording voltmeters a permanent record of station voltage is kept. On this switchboard are mounted the drum switches, which control the low tension and high tension bus-junction circuit breakers and the transformer and line circuit breakers referred to under "Alternating-Current Circuits."

The ammeters in the high tension feeder circuits are connected to the secondaries of the 44 000 volt series transformers, which are provided with double secondaries, one for meters and one for relays. The instruments connected in the low tension circuits are supplied from series and shunt transformers in the switching room, the former mounted in the cable wells back of the circuit breaker structure and the latter upon the walls of the room below the bus-bar structure and separated by marble barriers. The station and tunnel lighting circuits are also controlled from this board, double throw switches being provided, so that the lights can be supplied from either the direct-current bus-bars or a lighting transformer. Another double-throw switch is provided for transferring the control circuits from one bus-bar to the other. In addition to these there is also a double-pole single-throw switch for control of the gate hoist motor on top of the dam.

PROTECTIVE APPARATUS

*Lightning Arresters*—To protect the station against the effects of lightning disturbances and line surges, lightning arresters and choke coils have been installed. The arresters connect from line to ground, through disconnecting switches at the outgoing ports.

The choke coils are connected in series with the line between the transformer circuit breakers and the high tension sides of the transformers, their function being practically that of a buffer, resisting surges, and, through reflex action, precipitating discharges from lines to ground across the arresters.

## DATA ON GENERATING STATION

As shown in Figs. 4 and 5, the station is made up of two sections, a generator and a transformer house.

*Generator house*—250 by 37 feet, one story high, equipped with one 25-ton travelling crane.

*Transformer house*—72 by 85 feet, two stories high.

*Turbines*—Eight, 5 500 hp, twin horizontal, 72 feet head, 225 r. p. m., maximum efficiency at three-fourths gate corresponding to full load on generator: 82 percent.

*Feeder and draft tubes*—Feeder pipes, 16 by 18.5 feet at gates, 16 feet diameter at turbine case; draft tubes, 11 feet diameter at case and 18 by 11 feet at outlet; both feeder and draft tubes of 7/8 inch steel plates.

*Generators*—Eight 3 000 kw, three-phase, 2 200 volts, 60 cycle, two bearing-type, star-connected, one bar per slot, nine slots per pole, full-load efficiency 96 percent, designed to carry full-load continuously with a temperature rise not exceeding 35 degrees C. when operating at 100 percent power-factor and normal voltage.

*Exciter sets*—Two turbines, 700 hp at 450 r.p.m..; two generators, 400 kw, compound-wound, 250 volts, 1 600 amperes, to carry full-load continuously with a temperature rise not exceeding 40 degrees C.

*Transformers*—Twelve, 2 000 kw, oil insulated, water cooled, delta-connected on both low and high tension, normal ratio 2 200 volts to 44 000 volts, cylindrical boiler iron tanks.

*Switching equipment*—Control pedestals—Eight controlling generators, cast iron frame, sheet iron sides and back, marble front and top; mounting—circuit breaker controllers with red and green indicating lamps, rheostat hand wheel, field switch, voltmeter and synchronizer receptacles, synchronizing lamp, and reflector lamp on back for illuminating instrument post. Two pedestals for controlling exciters; mounting—voltmeter, ammeter, 2 200 ampere single-pole, double-throw knife switches and rheostat hand wheel. Two equalizer pedestals; mounting—one 2 000 ampere single-pole, single-throw knife switch.

*Instrument posts*—Six rigid and two with swivel top. Four posts, mounting—one bus-bar voltmeter, one machine voltmeter, one alternating-current ammeter, one direct-current field ammeter, one polyphase indicating watt-

meter. Two posts, mounting—one frequency meter, one alternating-current ammeter, one direct-current field ammeter, one machine voltmeter, one polyphase indicating wattmeter. Two swivel top posts, mounting—one synchroscope, one alternating-current ammeter, one direct-current field ammeter, one machine voltmeter, one polyphase indicating wattmeter.

*Panel board*—One station panel controlling bus junction circuit breakers; mounting—two graphic recording voltmeters, and knife switches for local circuits. Two transformer panels for low tension side of transformers; mounting—power-factor meter, ammeters and polyphase integrating wattmeters. Two feeder panels controlling high tension side of transformers and outgoing feeders; Mounting—200 ampere alternating-current ammeters. The last two panels are left blank for the present.

*Generator leads*—One 1 400 000 circ. mil, paper insulated, lead sheathed cable per terminal.

*Transformer leads*—Two 1 000 000 circ. mil, rubber insulated, lead sheathed cables per terminal.

*High tension leads*—200 000 circ. mil copper tubing, with requisite "T" joints and elbows covered with special insulating compound.

*Electrically operated switches*—Low tension—Eight, three-pole, oil immersed, double-break generator switches and five three-pole, oil immersed, 2 000 ampere switches, four for transformers and one for bus junction.

*Electrically operated switches*—High tension—Eight, three-pole, oil immersed, double-break, 45 000 k.v.a., 60 000 volts, four transformer switches, four line switches, also one bus junction switch.

*Choke coils*—Twelve, 80 ampere, 45 000 volts, oil insulated, self-cooled.

*Lightning arresters*—Twelve, low equivalent.

# GEORGE WESTINGHOUSE

The recent appointment of receivers for certain of the Westinghouse Companies has brought forth many words of appreciation from men of affairs and in the daily and technical papers. To our many Westinghouse readers, who have faith and confidence in the organizations created by Mr. Westinghouse, the following article from The Railroad Gazette will appeal with irresistible force.—Ed.

FOR a second time in a crisis this wonderful engineer appears near the center of the stage with the light turned on his financial constructions, and by the results of inspection and full knowledge these essential, but to him incidental, products of his genius must stand. Some things are certain in this uncertain world, and among them is the human certainty that his work will go on and will be conducted by him without other than slight check, because it is world's work, making materials which are the results of original study, invention and adaptation for the most part having to do with the arts of transportation, and all for saving life and producing better implements of civilizatiton. If there were doubt of this, if there were fear of his "going to the wall," it would be a matter of concern to every railroad officer who respects his profession and takes it seriously; and also to his business rivals, commercial enemies, who have never failed to acknowledge the indebtedness to this great inventor and producer.

There are 21 American and 10 foreign Westinghouse companies,* with 210 officers, $120 000 000 capital, $90 000 000 annual

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*The principal American companies are: American Brake Co., Atha Steel Casting Co., Bryant Electric Co., Canadian Westinghouse Co., Cooper-Hewitt Electric Co., East Pittsburgh Improvement Co., Nernst Lamp Co., R. D. Nuttall Co., Perkins Electric Switch Mfg. Co., Pittsburgh Meter Co., Security Investment Co., Union Switch & Signal Co., Westinghouse Air-Brake Co., Westinghouse Automatic Air & Steam Coupler Co., Westinghouse, Church, Kerr & Co., Westinghouse Electric & Mfg. Co., Westinghouse Foundry Co., Westinghouse Inter-Works Railway Co., Westinghouse Lamp Co., Westinghouse Machine Co., Westinghouse Traction Brake Co.

The principal European companies are: The British Westinghouse Electric & Mfg. Co., Ltd.; Societe Anonyme Westinghouse, La Havre, France; Societe Electrique Westinghouse De Russie; Traction & Power Securities Co., London; Westinghouse, Cooper, Hewitt Co., Ltd., Lon-

output, 24 factories with 7 000 000 feet of floor space, and an army of 38 000 employees. And these huge machines are not simply notable because they make most of the automatic brakes and a fair share of the signals, draft gear and electric light, power and traction materials for the civilized world. Their beneficent power and influence is due rather to the original investigation, invention and design and development which have been an incentive and a spur to other engineers and manufacturers.

So swift a pace was never before known as that set for getting full knowledge of how to control electric force for the uses of mankind; and few indeed of the great men who have made their mark in this field fail to credit that pace to Mr. Westinghouse. Probably the greatest single thing in this way which he has done was in introducing and developing in America the use of the alternating current for transmitting and applying electricity. He was one of the first to see the possibilities of the applications of the alternating current, and with his characteristic courage and vigor he proceeded to buy patents, to invent, to develop apparatus and methods and to push forward commercially along that line. He had a tremendous fight against established interests, but he has revolutionized practice, and the theories he sustained with such vigor and at such expense in money and personal comfort, are now accepted by the electrical engineers of the world.

He has sole credit for originating a method of stopping trains and controlling speed so as to make high speed and heavy train movement possible, and with the help of his staff he has been able

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don; Westinghouse Electricitats - Actiengesellschaft; Westinghouse Metal Filament Lamp Co., Ltd., London; Westinghouse Metallfaden-Gluchlampen fabrik Gesellschaft m. b. H.; Westinghouse Brake Co., Ltd., Compagnia Italiana Westinghouse Die Freni.

Some idea of the scope of the several manufacturing companies can be got from a brief list of their more important products: Electric apparatus of all kinds, train brakes, locomotive brakes, electric-car brakes, automatic slack adjusters, automatic air and steam couplers, friction draft gear, automatic and manual block signals, hand-operated and power-operated interlocking machines, gas producers, gas and water meters, steam and gas engines, turbines, mechanical stokers, air compressors. For installation and construction work, one of the larger corporations is occupied exclusively as designing and constructing engineers. For example, the company had charge of the layout and construction of the Boston South Terminal and now has the mechanical and electrical engineering and equipment of the Pennsylvania's New York terminal, involving an expenditure of $25 000 000.

during the past 38 years to successively improve and adapt that method to all new conditions. In doing this he has saved thousands of lives, directly in the actual train service, and indirectly, to a degree not measurable, in the resultant quick transportation of food, materials and people.

What may be called his second important series of studies for securing safety and increasing the capacity of railroads was to the same end of preventing collisions and permitting increased density of traffic. In invention and development of automatic block signaling and power interlocking he was one of the pioneers, and in results undoubtedly the most important of all of them. Our readers are fairly familiar with his work in these lines. They can, however have no conception of the tenacity of purpose and the prodigal expenditure of mental energy that have gone to develop the special arts and apparatus which are the reason for existence of the Air Brake Company and the Union Switch & Signal Company.

In the same line of thought he began more than twenty years ago studies and experiments in draft gear for the purpose of making it possible to haul long trains of heavily loaded cars, reducing the shocks and preventing the disastrous breakaways. Early failures in his friction draft gear meant nothing to him. He is classed as one of those who have "the courage of their convictions," but this is not accurately descriptive. His belief becomes his principle, and when he believes he acts on it with no thought of the quality of courage and no need to muster it. To him the success of the friction draft gear and its useful function were foreordained.

The briefest enumeration of the ways in which Mr. Westinghouse has made high-speed, heavy trains and more frequent trains possible and safe sounds like an eulogy, but there is no intention of that sort in this writing. It is, rather, to remind every railroad officer who honors his calling that this man who has done so much for us is facing a financial storm with the same quiet confidence that he has shown with hundreds of mechanical difficulties, and that he deserves to have the support of railroad officers, engineers and business rivals. He is capable of great work in this world for many years to come, and we must not lose the benefit of that work.

One contribution made by Mr. Westinghouse to the welfare of mankind is not known by many people outside of a limited district. He was a pioneer in the development of the method of using natural gas as a fuel. When he took up the matter its use was quite limited and was crude, wasteful and dangerous. He saw the methods

of transportation in handling gas must be revolutionized before it could be successfully used in a large and general way, and to his engineering sense is due the development of the successful method of transmitting gas in large volumes at low velocity and under low pressure.

At this time, in addition to an enumeration of his work, something about Mr. Westinghouse's personal characteristics may aid the younger generation to understand the situation. He is a man of great physical strength, he has lived an abstemious and sober life. He has never smoked a whiff, he never drinks anything but possibly a glass of wine with his dinner. He has always eaten sparingly and carefully and, while he has worked tremendously, his work has been widely varied and a succession of mental diversions, a substitute for amusements in keeping mind and body stimulated and elastic. Physically he seems as young as an ordinary business man of 45 or 50, and he has a reasonable expectation of 20 years of valuable work, although he was born in 1846.

Intellectually, he was probably never more powerful than he is to-day. It is to be supposed that the imaginative side of his mind is less vigorous now than it was twenty years ago, although that is by no means certain, because he is a man so phenomenal in make-up. In capacity for sustained attention, in power of analysis and reason, and in command of a vast store of experience, he is probably to-day a better man than he ever was before. All of this being so, it is impossible for those who know him to think of him as relaxing his efforts or suffering any diminution of power or control.

It would be quite impossible to even attempt to give any notion of the multitudinous interests into which his restless mind has penetrated, always with the aim of producing practical and useful results. For while he is a man of imagination and of visions, the governor of his mind is always set to the end of utility.

Why has he done this? Why has he set aside ease and pleasure? Why has he given his years to unceasing toil? Why has he repeatedly ventured fortunes in great enterprises? He might have retired at 40, a very rich man with a name known and honored all over the civilized world, with a great capacity for enjoyment and with abundant means to gratify all the tastes and desires of his enterprising and versatile spirit. Probably Mr. Westinghouse himself could not answer these questions. He has worked as all great men have worked—in obedience to an internal, compelling force.

It is certain that the desire to amass and leave behind him a colossal fortune has been the most insignificant element in the forces that have driven him forward. It is certain, also, that he has always felt a noble aspiration to do good in the world, to really serve mankind. Unquestionably, he loves power and responsibility. Unquestionably, too, he is keenly alive to the good opinion and the approbation of the best minds. But it is very doubtful if these recognized incentives to exertion and to self-sacrifice have been other than contributory to the main result. Behind it all lies that mysterious, impelling force (the definition or analysis of which is perhaps impossible) which pushes men forward as fast and as far as their powers permit them to go. The directions which they take, the results which they achieve, depend upon the qualities of their minds and on their moral natures; and these we can discern and analyze, but the driving power behind is often beyond our comprehension.

The sources of his power over men are perhaps easier to discern than are the underlying motives of his conduct. Men feel immediately the dominating force of his will. They recognize at once when they come in contact with him the breadth and power of his intellect. And then, as they go on, they discover his generosity, his magnanimity, the loftiness and purity of his motives, and they are attracted by the simplicity of his manners. People often say that he has great personal magnetism. So he has—whatever that may mean. But, after all, that is merely an easy phrase in which to sum up the resultant of the noble qualities of his mind and character.

# ELECTRIC DRIVE IN IRON AND STEEL MILLS

W. EDGAR REED

ALTHOUGH electric motors have been used to drive the auxiliary apparatus in iron and steel works, their application to the large rolls is only of comparatively recent date and is the most useful of the recent applications of electricity. The increasing application of electric drive is due partly to the economy of transmission and distribution, partly to its reliability and partly to the ease and facility of control. Electricity offers also, in most cases, the most efficient and elastic system of transmission of power. It requires simply a few properly insulated wires for the transmission of even great amounts of power for long distances, and, with the loss of only a few percent, a part or all of the load can be easily and quickly cut off or thrown on as required without injury to the system. These features permit the centralization of the smaller generating stations which are required by other systems, the averaging of intermittent and varying loads and generally increased production. This means a great decrease in the cost of power and in the required capacity of the stations. The advantages are so well understood and the system now so thoroughly tried that there is no hesitation in using electric drive for even the most severe and exacting conditions met in large continuous or reversing mill work.

Heavy mill work requires a drive capable of standing intermittent and excessive loads and it is of the greatest importance to have at the same time a very flexible coupling between prime mover and rolls in order to reduce the cost of repairs to a minimum. Electricity offers the most flexible connection known and is the system best suited to the excessive variations in power required. Fig. 1 will given an idea of the variations in power required for a two-high reversing mill. From this figure it may be seen that the maximum variations are about 3 500 hp in a few seconds.

Power for iron and steel mills may be purchased outside or generated at the mills and is generally derived from water falls, steam, or gas engine-driven electric generators. The waste gases from blast furnaces, when close to the generating station, offer a comparatively cheap source of power. These waste gases are now utilized for this purpose especially in countries where the cost of fuel is comparatively high. Even in Pennsylvania where coal is

very cheap it has been found advantageous to use blast furnace gases for the generation of power.

When power for a mill is bought from an outside company, which also furnishes power from its system for other purposes requiring good voltage regulation, large fluctuating loads would be objectionable. The excessive intermittent loads common in mill work, especially if the driving motors in the mills are large compared with the capacity of the power station, may seriously affect the regulation. Under these circumstances the cost of power may be very high unless some method is used to equalize or smooth out the large variations in power. The maximum power required, although it may last for a short time only, determines the maximum size of the complete station and the cost of power. For this reason it is often sold on the basis of the maximum instead of the average or total power consumed. It is therefore very desirable to reduce the maximum demands or peak loads as much as possible in order to secure improved regulation and reduce the cost. The smoothing down of the peak demands will at the same time improve the efficiency of the system by allowing a fairly constant load approximating full-load to be placed on the central station apparatus.

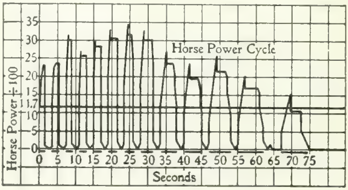



FIG. 1—HORSE POWER CURVE FOR A TWO-HIGH REVERSING MILL

METHODS OF EQUALIZING

*Continuous Mills*—When the maximum load lasts but a few seconds, the peak overload may be reduced to satisfactory values by increasing the kinetic energy which the rotating parts give up as the heavy overload comes on. This is accomplished by increasing the fly-wheel effect by adding weight to the rotating elements or placing a fly-wheel on the motor shaft and at the same time designing the motor or control so that the speed drops rapidly as the heavy overloads come on. Increasing the fly-wheel effect reduces the maximum overload on the motor and line, and by suitable design this overload can be made any desired amount.

*Reversing Mills*—When the rolls are to be reversed the kinetic energy or fly-wheel effect of the reversing parts should be reduced to

a minimum, instead of being increased, as was the case for continuous mills, in order to reduce the energy required in reversing. Some mills are reversed at three second intervals for several passes. The time then increases for succeeding passes. Another method of equalizing loads is required for this kind of mill service. One form of equalizer that is suitable for these requirements consists of a motor-generator fly-wheel set connected between the roll-driving motor and the source of power. The general arrangement and connections for such a set are shown in Fig. 2. This system has been found to be very efficient in equalizing the large variable and intermittent loads found in large reversing mill work. The system can also be used to good advantage in many cases for driving small mills.

This equalizer set consists of an induction motor with an exter-

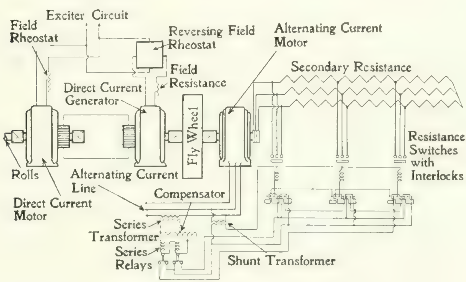



FIG. 2—DIAGRAM OF CONNECTIONS FOR EQUALIZER SET

nal resistance in the secondary circuit, driving a fly-wheel and a direct-current generator. A direct-current motor having drooping speed characteristics could be used in place of the induction motor. The direct-current generator is electrically connected to the roll motor whose speed and reversing are controlled by regulating or reversing the generator field current. In slowing down the field of the generator is weakened and the roll motor reverses the current through the generator, thus tending to operate the generator as a motor and act as a dynamic brake on the roll motor. Both motor and generator may have auxiliary poles to insure good commutation.

The alternating-current motor is of the wound rotor type which permits the use of variable resistances in the rotor circuits and the use of a slip regulator for producing a variable speed motor. By the use of this equalizing method a nearly constant sup-

ply of current may be taken from the line independent of the power being delivered by the roll motor. When the load comes on the direct current generator, the fly-wheel gives up energy and supplies that portion of the power required in excess of the average.

In order that a fly-wheel may give up its kinetic energy when the excessive overloads come on, it is necessary that its speed decrease. The greater the decrease in speed (in a given time), the more energy will be given up, as the kinetic energy in a given wheel is proportional to the square of its speed. This is accomplished by making the speed of the motor automatically adjustable by inserting resistance in the rotor winding and thus varying the slip. The slip of an induction motor increases with increase of load, but the normal slip is fairly low and the corresponding drop in speed small. The slip is also increased with the increase of rotor resistance.

The efficiency of the induction motor varies inversely as the slip, each percent increase in slip meaning approximately one percent decrease in efficiency. The slip required of these motors depends upon the value of the peak overload, its duration and interval between peaks, as well as upon the fly-wheel effect of the rotating parts. It can generally be adjusted for values up to approximately 20 percent; a motor having 16 percent slip at full-load would have approximately 24 percent slip at 50 percent overload. This 20 percent decrease in speed would require the fly-wheel and all other rotating parts of the set to give up approximately 42 percent of their total kinetic energy.

Two relays are placed in the circuit which supplies the induction motor. These relays are arranged to change the secondary resistance of the rotor so that the motor may drop in speed as the load increases without drawing a greater current from the line. Both relays are closed when starting or at light loads. As the speed increases the resistance switches are closed by the rotor current, first one, then two, three, four, etc., until the current in the induction motor reaches the desired maximum, when the first relay opens the auxiliary circuit so that no more switches can close. When a heavy load comes on the fly-wheel gives out energy and slows down, allowing more current to be taken from the line. This causes the second relay to operate and cause the resistance switches to insert more resistance in proper order again. This adjustment forces the fly-wheel instead of the motor to take the greater part of the intermittent load by giving up part of its kinetc energy which was stored up before the overload came on. This equalizes the irregu-

larities and gives a fairly constant load on the induction motor and all other apparatus back of it; makes an exceedingly flexible connection between prime mover and load, and procures good voltage regulation of line. This is essential when lights and some other kinds of apparatus are operated on the same circuit as the motors and the conditions of motors operating auxiliary apparatus is also much improved, as a drop in voltage means a reduction of the starting and pull-out torques of shunt and compound-wound direct-current motors or induction motors. The torque and output of an induction motor varies as the square of the applied voltage, hence a 10 percent reduction in voltage would therefore mean approximately 20 percent reduction in maximum starting and pull-out torque.

If power is bought outside, such a system would certainly be required and it is also advantageous where power is generated by the mill company. Some idea of the importance of such a system can be seen from an installation which required 4 000 horse power in driving motors and only 1 400 horse power approximately in the motor of the equlizer set and all apparatus back of it, including the transmission line, switch-board, instruments, electric generator, engines, boilers, and fuel.

*Continuous Mill*—Among the many installations that have been made recently is the following: Two 1 500 horse power, compound wound, 220 volt, 100-125 r.p.m., direct-current motors at the Edgar Thomson Steel Works for driving continuous rail mills. These motors are direct-connected to the rolls. Special attention has been given to the mechanical design. The bearings are of the oil ring and forced circulation babbit lined type, 25 inches in diameter and 62 inches long. They are also arranged for water cooling. The motor is also very liberally designed and commutation is exceedingly good. A 125 000 pound cast steel segmental fly-wheel 18 feet in diameter is mounted on the motor shaft to assist in equalizing the load on the motor and power house. The speed of the motor drops from approimately 125 to 90 r.p.m. in actual operation, which allows the fly-wheel to take care of the peak loads.

*Reversing Mills*—Installation at the Hildegarde Works—(Austrian Silesia)—This mill is for rolling two-ton ingots down to billets for making girders, rail, etc., and for the first passes should reverse every six to eight seconds. The mill is driven by a four bearing set of three direct-current motors. These motors are connected together by two rigid couplings and are divided into three units in order to keep the inertia of the rotating parts as low as

possible as well as for manufacturing advantages. The normal rating of each motor is 1 200 horse power at 330 volts and speeds obtained are from 0 to 120 r.p.m. The maximum horse power of each motor is 3 000 which makes 9 000 horse power maximum for operating the ingot mill. The motors have series and shunt separately excited windings, and the armatures are connected in series.

The equalizer is a four bearing set consisting of an induction motor, two direct-current generators and two fly-wheels and runs at 375 to 310 r.p.m. The fly-wheels are made of cast steel, are 13 feet in diameter and each one weighs about 26 tons. Water-cooled brakes are mounted on the wheels for stopping the set quickly in case of necessity. The two direct-current generators and the three mill motors are connected permanently in series, the mill motors being controlled and reversed by the field current of the generators. This control is easily and quickly operated. When reversing the set acts as a brake for the mill motors and energy is returned to the equalizer set. The speed of the induction motor is controlled automatically by inserting the resistance of a water rheostat in the rotor circuit

The power taken from the generating station does not exceed 25 percent of the maximum power required for operating the mill.

Installation at the Illinois Steel Works—This 30-inch two-high plate mill is driven by two 2 000 horse power, 575 volt normal rating direct-current shunt-wound motors mounted on a common shaft. The speed varies from 0 to 150 r.p.m. The mill should be capable of reversing every four to six seconds. Good commutation is secured at low voltages and heavy currents by the use of commutating poles and compensating coils wound in slots in the pole faces. The power taken from the generating station is approximately 30 percent of the maximum power taken by the mill motor.

# ELECTRICALLY-OPERATED SWITCHBOARDS (Concl.)

B. P. ROWE

### ELEVATED PANEL INSTRUMENT SWITCHBOARDS

The arrangement shown in Fig. 8 is often required in generating stations and sub-stations where electrically-operated apparatus is controlled from a sectional controlling desk, and a concentrated

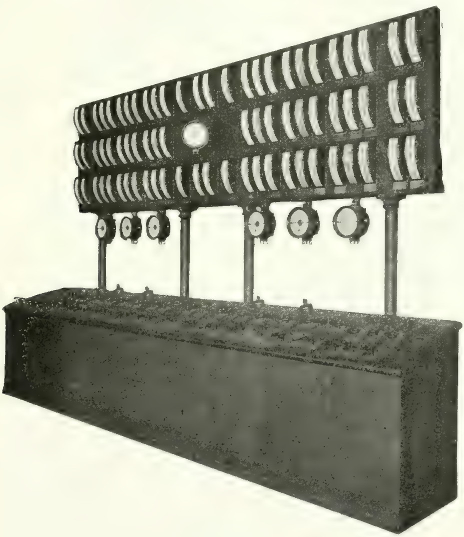


FIG. 8—CONTROLLING DESK AND ELEVATED PANELS FOR EDGEWISE METERS

panel board is required with each panel, the same width as the corresponding section of the desk. These panels require less room than instrument posts, and are elevated to prevent any obstruction to the operator's vision. The disadvantage is usually that some special framing is required or braces at the top to support the panels and prevent tipping unless a specially rigid frame and floor supports can be obtained.

WATTMETER AND RELAY PANELS

It often happens that a station is equipped with a large number of relays and recording wattmeters, and that the large number of indicating instruments supplied in connection with these other devices is too great to make a compact and convenient arrangement if they are all mounted on the instrument switchboard in the operating gallery. On the other hand, as wattmeters and relays usually operate on separate circuits from the indicating meters, a separate location near the meter transformers, which permits the use of short leads, is often desirable. As the wattmeters and relays are not required to be consulted very often by the operator, a separate location is not objectionable. In such a case they may be located on a separate relay panel, as shown in Fig. 9.

FIG. 9—RELAY PANEL

EDGEWISE TYPE FEEDER SWITCHBOARDS

A feeder switchboard which is adapted for use in installations where a large number of feeders must be concentrated into a small space, so as to be directly under the hand of the operator, is shown in Fig. 10. The panels shown are of planished steel as no live parts need to be mounted thereon, rendering the use of marble unnecessary. By this arrangement a feeder circuit with indicating instruments occupies a section six and one-half inches wide, two feeders being shown for each thirteen inch section. Integrating wattmeters can be mounted below the controllers if desired.

Fig. 11 shows a marble switchboard which has vertical edgewise meters mounted at the top instead of round-pattern instruments. It is noticeable that the use of edgewise meters does not reduce the width of panel as much as would be expected when substituted for round-type meters, because they are usually mounted in a row as shown, and the round-type meters could be used by appro-

priating just a little more space. But there is undoubtedly a more economical utilization of space on the panel where edgewise meters are used than where the meters are round pattern.

FIELD RHEOSTATS AND FIELD SWITCHBOARDS

If the generator control apparatus is located on a panel the field

FIG. 10—ALL STEEL SWITCHBOARD WITH VERTICAL EDGEWISE METERS

rheostat can be conveniently operated by means of a hand-wheel geared directly to a face plate on the rheostat by gearing or chain and sprocket. If the rheostats are electrically controlled from a distance through face plates, they should have a small motor geared

to the contact arm, the motor being controlled from the operating platform and the field switches electrically operated.

DIRECT-CURRENT EXCITER SWITCHBOARD

The switchboard for control of the exciter is sometimes placed in the operating gallery when this is not too remote from the machines. In other cases it is placed on the station floor as near as convenient to the exciters. It is usually a typical direct-current board. While the most serviceable ones have entire panels finished in black marine, a large number of stations are using blue Vermont marble. The circuit breakers used are non-automatic, being used only to trip by hand when the circuit is to be interrupted, to prevent an arc from burning the switch. Some station managers prefer reverse-current breakers in the exciter circuits, but the usual practice is to omit protective devices.

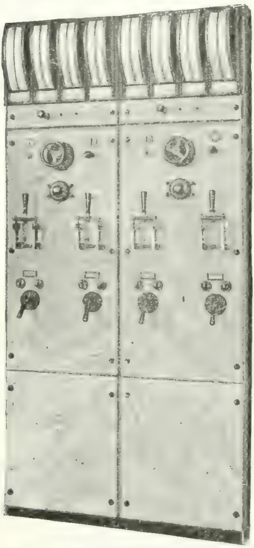


FIG. 11—ALTERNATING-CURRENT SWITCHBOARD PANELS WITH VERTICAL EDGEWISE METERS

STATION APPARATUS

In addition to providing for station voltmeters, synchroscopes and wattmeters, either on panels or an instrument post, it is often necessary to install static ground detectors. These are always operated through condensers so located that the wiring is short and the conductors properly separated and far enough from neighboring metal so as not to interfere with the operation of the instruments. This is best accomplished by installing the ground detectors on the station wall or on suitable supports near the condensers if it is difficult to properly run the leads to the operating gallery.

While the station indicating instruments may be provided for as described previously, or located on swinging brackets attached to the panel switchboard it is often an advantage to be able to locate station-recording apparatus such as integrating wattmeters, recording ammeters, relays, etc., on a separate switchboard.

### AUXILIARY DIRECT-CURRENT CIRCUITS

Direct current for operating the oil switches and other apparatus may be obtained as follows:—

From auxiliary storage batteries.

From motor-generator sets.

From direct-current exciter systems or other direct-current bus-bars.

It must be especially noted that where the exciter system is controlled by a Tirrill regulator, the voltage fluctuation is likely to be so great that it cannot be relied upon for standard electrically-operated apparatus. In this case either a small storage battery or a motor-generator set must be relied upon to supply the energy. In cases where a storage battery must be employed owing to such considerations, and no charging current is available, a Cooper-Hewitt mercury rectifier may be relied upon to charge the battery.

In cases where it is absolutely necessary to operate oil circuit breakers from direct-current exciter systems which are connected to Tirrill regulators, the coils can generally be specially wound so as to operate at a low voltage, and the magnetic circuit be designed to saturate at high voltage so as to keep the switch from closing with too much force.

### CONTROLLING AND INSTRUMENT SWITCHBOARD

Under this head will be considered the installation of controlling switches and accessories that control electrically-operated oil switches. In this connection it is essential to make sure that direct current is available at a suitable voltage to operate the electrically operated devices. Controlling devices are designed to operate from 125, 250 or 500-volt circuits, but when the potential is liable to drop below 80 volts, operating coils must be specially provided for the low voltage. The controlling apparatus can be mounted on the face of the switchboard panel together with the instruments where the system is simple and an inexpensive arrangement is desired Nearly all large stations have the generator control apparatus mounted on control desks or pedestals. A feature of some control outfits is the use of miniature bus-bars with lamps and indicators in the circuits. By means of these bus-bars the entire main station connections are embodied in miniature on the controlling desk and, if the indicators or lamps are placed in the miniature circuits, the switching operations can be seen to take place

when the operator moves his controller exactly the same as they occur in the main circuit. When the desk type switchboard is used, it is usually placed directly in front of the instrument switchboard and the operator has his control apparatus arranged, as nearly as possible, opposite the respective instrument panels. The usual type of controlling desk is not like a panel switchboard and does not lend itself to future extensions without alterations, unless it is built and installed in sections.

The arrangement of control apparatus in groups so that the units of control can be handled the same as panel switchboards seems to be the ideal. Nearly every large installation starts with a few generating units and increases as the demand for power increases. To meet the demand for such installations, control pedestals are made which embody all the desirable features. They generally contain controllers, indicators and lamps for the oil circuit breakers, synchronizing plugs and lamps, voltmeter plug, electrically-operated rheostat controller, a controller for the engine governor to change the speed in synchronizing the generators, and a controlling device to open and close the electrically-operated alternating-current generator field switch. These pedestals occupy a floor space about 16 inches square, and are not high enough to obstruct the operator's view. When pedestals are used, instrument posts are ordinarily placed at the edge of the switchboard gallery with the meters facing the operator who stands at the control pedestal and faces the station, thus having an unobstructed view of the generators to be controlled. When an instrument switchboard is used, unless it is of the elevated panel type, conditions are reversed, as the operator must turn his back to the station in order to see the instruments which are located on the instrument switchboards. When controlling pedestals are used, the feeder switchboard is located in the rear of the pedestals so that the operator can be within easy reach of all the controlling apparatus.

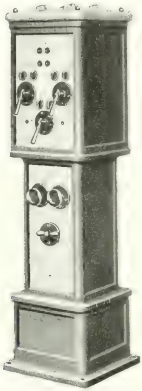


FIG. 12—CONTROLLING PEDESTAL

The usual method of controlling feeder circuits is to place the controllers on the switchboard directly beneath their respective feeder instruments.

In conjunction with the instrument post a station post is used, which supports the voltmeters and synchroscopes. It usually stands

in a central position in the gallery and the whole top is arranged to swing on a swivel, so that the instrument may be seen from any point in the gallery. A similar post is also provided on which a large synchroscope three feet in diameter, is mounted, the correct position of the dial for synchronizing being indicated by a lamp; another lamp on the pointer of the instrument shows by its position on the dial whether the machine is running fast or slow or indicates synchronism. This synchroscope can be operated in parallel with the synchroscope in the gallery.

GENERATOR CONTROL PEDESTALS

For auxiliary controlled switchboard apparatus, mountings must always be provided for the control apparatus of each generator.

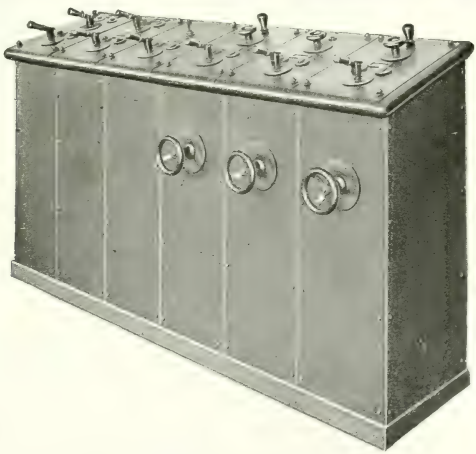


FIG. 13—SECTIONAL CONTROLLING DESK

The concentration of the control apparatus for each generator on a single pedestal as a unit of the control system provides a simple and ready means for making the initial generator control apparatus installed in a large power station complete in itself, without reference to what is to follow. This possesses marked advantage over the desk form of control switchboard, which, if not of the sectional type, must usually be laid out for the entire final station control apparatus at the start and either made with one end temporary for future extension or else drilled for the entire set of control apparatus and the holes plugged temporarily.

The pedestal as shown in Fig. 12 is designed to take the following apparatus:—Signal lamps, six oil circuit breaker indicating lamps, three oil circuit breaker controllers, one voltmeter plug and receptacle, two synchronizing plugs and receptacles, one controller for engine governor motor, one controller for electrically-operated field rheostat, one control switch for electrically-operated field discharge switch, and one control switch for engine signal.

*Steel Controlling Desk—Sectional Type*—This type of controlling desk, as shown in Fig. 13, has an iron frame enclosed by paneled steel sides and a marble top. The construction is such that each top panel with its corresponding paneled sides forms a section, and the desk may be extended in either direction by installing additional sections, the end panels and end moulding being removable in one piece to provide for inserting the necessary additions. The sections may be made of lengths to suit the necessities of each installation, but the standard lengths are 12, 16, 20, 24 and 32 inches.

### CALIBRATING JACKS

In many installations it is desirable to have jacks or receptacles provided in the series and shunt transformer circuits so that standard meters with suitable plugs attached may be connected in these circuits for comparing the readings of the switchboard meters with the standards.

There are two kinds of these receptacles, one for establishing a loop in a series transformer circuit and used for an ammeter plug receptacle, and the other a double-pole receptacle for use on shunt transformer circuits.

From the general description given in the foregoing pages it will be seen that the switchboard installation should be taken into account when making the preliminary designs of a station, for if this is not done, and the conductors and structural work provided for in a suitable manner, it will be found difficult, if not impossible, to install the switchboard equipment in a satisfactory manner.

# CIRCUIT-INTERRUPTING DEVICES—II

## KNIFE SWITCHES

WM. O. MILTON

THE simplest form of circuit-interrupting device is the knife switch. While it is comparatively simple in construction there have been, in the process of its development, many designs varying in the kind and quality of material used, methods of assembling parts and service requirements. The purpose in this article is to consider those features of design which are used in good practice. In the design of switches consideration must be given to the mechanical strength, carrying capacity, breaking capacity and insulation.

The National Board of Fire Underwriters, representing the insurance interests of the country, after a conference with the manufacturing and construction companies, have formulated their National Electrical Code which governs the design and construction, application, installation and method of operation of electrical apparatus. The object is to establish standard forms of apparatus giving due consideration to the important bearing that these features have on fire risk. Accordingly, the standard of excellence of a piece of apparatus is, in general, accepted as established when it has been "approved" by the Underwriters.

### CARRYING CAPACITY

It is almost universal practice to make switches of the best hard drawn copper as advised in the Underwriters' rules. Rule 51f of the National Electrical Code reads as follows: "All switches must have ample metal for stiffness and to prevent rise in temperature of any part of over 50 degrees F. at full-load, the contacts being arranged so that a thoroughly good bearing at every point is obtained with contact surfaces advised, for pure copper blades, of about one square inch for each seventy-five amperes." Some companies use 800 amperes and others 1 000 amperes per square inch cross-section area of copper. It is common practice on cables even when rubber insulated and used in confined places, to allow about 800 amperes per square inch cross-section area. It would seem perfectly logical, therefore, on switches which are almost invariably exposed to the circulation of air, to work the copper at the higher value given above, that is, 1 000 amperes per square inch. When the quantity

advised for sliding contacts is departed from, the tendency is to be more liberal, some manufacturers allowing as much as one square inch for each 50 amperes. Any trouble due to heating is almost always found at the contact surfaces and from this it would seem advisable to use the more liberal value. Some government specifications require contact surfaces of at least one square inch for each 50 amperes. With any of the values just given there is little trouble in keeping the temperature rise within 50 degrees F on direct-current. On alternating current, however, especially at sixty cycles and with large currents, it is much more difficult to keep within this temperature limit. In fact it is hardly practicable to build a switch of more than 3 000 amperes capacity for alternating-current service. The excessive heating on alternating current is due to skin effect.

The question of temperature rise, however, depends not only on the amount of heat generated, but also on the radiation. In this the base plays an important part. A slate or marble base is very efficient in radiating heat and it is assumed that the switches are so mounted for the test covered by Rule 51f above. A switch mounted on wood will run much hotter because wood is not a good conductor of heat nor does it radiate well. The base must be non-combustible and non-absorptive, for which further reasons the use of wood cannot be considered advisable.

*Overload Capacity*—There are frequent inquiries in regard to the overload capacity of switches. As the radiation increases somewhat more rapidly than the rise in temperature, and as the heat generated varies as the square of the current, it is evident that the temperature rise will be somewhat less than proportional to the square of the current. Thus a switch which will carry 1 000 ampers with 20 degrees rise will carry 2 000 amperes with about 60 degrees rise.

*Breaking Capacity*—The requirements of the test for current and voltage breaking capacity are covered by Rule 51i which reads thus:—"Knife switches must operate successfully at 50 percent overload in amperes and 25 percent excess voltage, under the most severe conditions with which they are liable to meet in practice." In order to insure the successful operation of a switch under these conditions long series of tests were made to determine the minimum break distances and spacing between poles. Rule 51k gives these minimum values for 125, 250 and 600 volts. The requirements for 250 volt service are given in Table I.

TABLE I—SHOWING MINIMUM BREAKING DISTANCES AND SPACINGS BETWEEN POLES OF KNIFE SWITCHES FOR 250-VOLT SERVICE

| Amperes | Minimum separation of metal parts of opposite polarity | Minimum break distance |
|---|---|---|
| 10 or less | 1 ½ | 1 ¼ |
| 11— 30 | 1 ¾ | 1 ½ |
| 31— 100 | 2 ¼ | 2 |
| 101— 300 | 2 ½ | 2 ¼ |
| 301— 600 | 2 ¾ | 2 ½ |
| 601—1 000 | 3 | 2 ¾ |

If spacings used are less than those specified in this rule, trouble will be experienced in obtaining the approval of the Underwriters. It is not safe to use any smaller distances if the switch is to be relied upon to open the circuit under the conditions of test in Rule 51i.

*Capacity on Alternating Current*—It is an interesting fact that with a given current a switch will break about double the voltage or twice as much power on alternating current as on direct current. This is due to the zero point in the alternating-current wave which facilitates the interruption of the circuit. In Rule 51k, therefore, there is the statement that, "for 100 ampere switches and larger, the above spacings for 250 volts direct current are also approved for 500 volts alternating current."

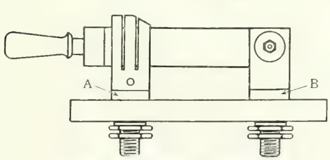


FIG. 1—KNIFE SWITCH

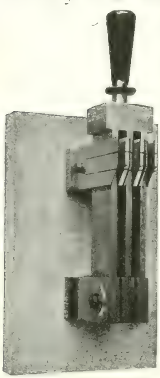
TESTS

*Drop and Insulation*—While a switch must stand the test under Rule 51i, this is not ordinarily made since the satisfactory operation of the switch is assured if the spacings are not less than those specified. The tests actually applied to every switch are a drop test and an insulation test. The drop test consists in taking the drop (from *A* to *B*, Fig. 1) across the switch at full-load. This should not exceed about 12 milli-volts from jaw block to jaw block. The principal object of this test is to insure good contact between the jaws and blade. Besides, a reasonably small temperature rise is assured if the drop is low. The insulation test consists in testing between break and hinge jaws with switch open, between opposite poles, and from jaws to ground. In the test from 3 000 to 5 000 volts are used, the principal object being to test out the base. Slate in particular requires a careful test on account of metallic veins which frequently occur and which would cause undesirable leakage. In

order to prevent surface leakage the distance from nearest live metal part to ground should never be less than one-half inch.

DETAILS OF CONSTRUCTION

*Cross Bars*—The material of the cross bar is an important matter as it must be mechanically strong and afford insulation between adjacent poles. There are several moulded compositions which afford sufficient insulation but they are almost always weak mechanically. Fiber is strong mechanically and good electrically when dry and of good quality. But fiber will absorb a certain amount of moisture and traces of acid are liable to be left during the process of manufacture, both of which may cause leakage of current. Besides, in long, thin cross bars, fiber is liable to warp badly. Wood, when thoroughly dried and treated so that it will not absorb moisture, is the most satisfactory material. It makes a strong cross bar which will not warp and will not permit any undesirable leakage of current.

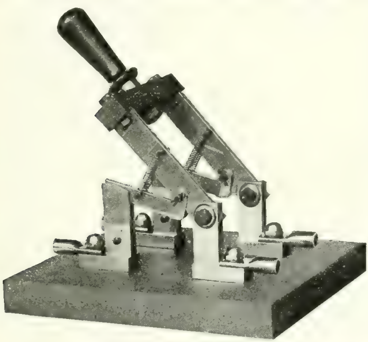


MULTIPLE BLADE KNIFE SWITCH
Single-Pole, Single-Throw, Rear Connection.

*Multiple Blade*—Switches of 1 000 amperes capacity and less are generally single blade while the larger capacities are made by combining two or more blades per pole. Thus the blades of 2 000 ampere and 3 000 ampere switches are generally made by combining two and three 1 000 ampere blades respectively. This is necessary in order to obtain sufficient contact surface without making the blades and jaw of abnormal width.

*Quick Break*—Auxiliary breaks are required by the National Electrical Code on switches "designed for use in breaking currents greater than 100 amperes at a pressure of more than 300 volts" and are recommended for all switches for over 300 volts. These auxiliary or quick break attachments make it impossible to draw a dangerous arc by opening the switch slowly. They are somewhat objectionable, however, both from the standpoint of cost and for mechanical reasons. The quick break attachment is generally the first part of the switch to get out of order. Unless the switch is to open the circuit with current flowing it is much better to omit this feature.

*Terminal Lugs*—Terminal lugs may be of brass or copper. The conductivity of ordinary cast brass is quite low, being frequently less than 15 percent of the conductivity of pure copper. Hence it is not usually considered good practice to use brass terminals for conductors larger than 0000 wire which corresponds to about 200 amperes carrying capacity. In the design of lugs all sections should be large enough to allow about one square inch for each 800 amperes where copper is used and for brass lugs the sections should be larger in proportion to the reduction in conductivity. Lugs are usually clamped between two nuts and the clamped surface through which current passes should allow about one square inch for each 100 amperes. For thread surface through which current must pass to the stud the usual rule is to figure the amount of cylindrical surface as if it were not threaded and allow 200 amperes per square inch on this basis. Thus on a one inch stud a nut 3/8 in. thick will take care of $1 \times 3.14 \times 3/8 \times 200 = 235.5$ amperes. All of the values given above are rather liberal for small currents of say 100 amperes and less, on account of the proportionately larger radiating areas.



DOUBLE-POLE, SINGLE-THROW, FRONT CONNECTION KNIFE SWITCH WITH QUICK BREAK ATTACHMENT

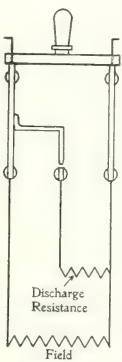
*Terminals*—Switches for use in switchboard work have rear connections, that is, the jaws have studs projecting through the switchboard, connection being made by means of terminals in the rear. Most switch manufacturers build switches of this design up to 3 000 amperes capacity. Larger switches are frequently built for direct-current work, but these are more or less special.

Front connection switches are not built for such large currents. They are generally isolated from the switchboard and mounted against the wall for controlling lights or motors where very large currents are not required. Mechanical difficulties are met with in the design of front connection switches of large capacity. For instance, if the terminals are placed at the ends of the jaws, then, in order that the handle may clear the cables, the jaws must be made

very high. This could possibly be avoided by placing the terminals at the side, but this construction would be awkward. Generally the capacity of front connection knife switches does not exceed 300 amperes.

### MODIFIED FORMS

*Field Discharge*—There are several modifications of the standard designs of knife switches which have important applications. The field discharge switch, for example, has an extra jaw and an attachment to the blade by which, on opening the switch, the field of a machine is shunted through a resistance. This resistance gradually absorbs the current and thereby prevents injury of the field from the inductive kick resulting from the sudden opening of the circuit. These switches are always made quick break in order that the discharge attachment may make contact before the switch opens and may open before the switch closes.



CONNECTIONS FOR FIELD DISCHARGE SWITCH

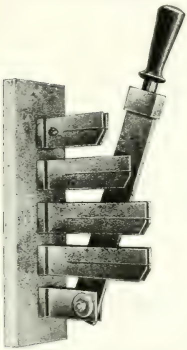
*Motor Starting Switches*—These switches consist of single-pole switches with extra break jaws and are used in starting direct-current generators, motor-generator sets and rotary converters from the direct-current side. Resistances are connected between the several break jaws. On the first step the entire resistance is connected in series with the armature. This is then short-circuited one step at a time until the whole is cut out and full voltage thrown across the machine. For heavy currents a device of this kind is very satisfactory and much cheaper than a starting rheostat.

For starting large alternating-current motors an auto-starter switch is commonly used. For a two-phase motor this is a four-pole, double-throw switch with two extra break jaws on one side by which taps from the auto-transformer give a reduced voltage for starting. After the motor has come up to the speed corresponding to the lower voltage the switch is thrown over to the full voltage position.

### INSTALLATION

A switch should be mounted so that gravity will tend to open it. The break jaws should be above the hinge jaws so that the

handle has to be thrown up to close the switch. Double throw switches may be mounted horizontally, but as this looks awkward on a switchboard, a stop is often provided on the hinge jaw which can be shoved under the blade so as to hold it in the open position. It is preferable when installing a switch to connect it so that the break jaws will be alive and the blades dead when the switch is open. The reason for this is that the blades stick out so much further from the base than the jaws that there is more danger of coming in contact with them or accidentally short-circuiting them.



MOTOR STARTING SWITCH

### OPERATION

To open or close a knife switch would seem to be the simplest operation imaginable. However, one not accustomed to operating switches, unless instructed beforehand, is almost sure to do it wrong; that is, he will go slowly and watch closely in order to see what is going to happen. As a result he draws an arc on opening the switch, getting a flash in his eyes as well as burning the switch. On closing the switch he is liable to see a spark and jerk the switch back open, thus drawing an arc when the switch may never have been intended to open the circuit. The proper way to operate a switch is to turn one's face away from it and then throw it in or open it quickly, let happen what may.

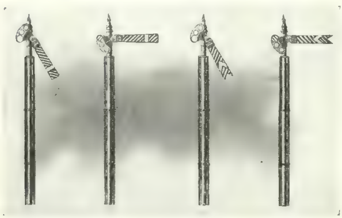
# RAILWAY SIGNALING—IX. (Concl.)

## THE LANGUAGE OF FIXED SIGNALS

W. E. FOSTER

BLOCK signals are used to indicate the presence or absence of trains between definite points. Automatic block signals usually indicate more than this because they indicate the condition of the track as far as broken rails or misplaced switches are concerned. During the past few years when the railroads have been having so much trouble on account of broken rails, automatic block signals have been a great protection. On one road as many as a dozen cases of broken rails in one month were indicated by their automatic block signals and serious wrecks were doubtless prevented.

WHITE RED GREEN YELLOW BLACK



Proceed Stop Proceed Caution
Home Signal Distant Signal

FIG. 7—ONE-ARM, HIGH, TWO-POSITION AUTOMATIC HOME AND DISTANT BLOCK SIGNALS

MEANINGS

*Home Signals*

*Proceed*—Block is in condition for train to proceed.

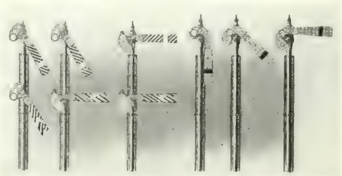
*Stop*—Stop and wait prescribed time, then proceed with caution, expecting to find train in block, misplaced switch or broken rail.

*Distant Signal*

*Proceed*—Expect to find next home signal in proceed posititon.

*Caution*—Prepare to stop at next home signal.

In appearance automatic block signals of the one-arm type shown by Fig. 7 cannot be distinguished from the interlocked signals shown in Fig. 1 in the November issue, although their meaning is different. This similarity has caused some roads to place a marker, such as an illumi-



Proceed "A" "B" Stop Proceed "A" "B" Stop

FIG. 8—TWO-ARM, HIGH, TWO-POSITION AND ONE-ARM, HIGH, THREE-POSITION AUTOMATIC HOME AND DISTANT BLOCK SIGNALS

MEANINGS

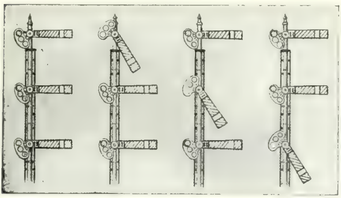
*Proceed "A"*—Block is in condition for train to proceed. Expect to find next home signal in proceed position.

*Proceed "B"*—Block is in condition for train to proceed. Prepare to stop at next home signal.

*Stop*—Stop and wait prescribed time, then proceed with caution expecting to find train in block, misplaced switch or broken rail.

nated letter *A*, on each of their automatic block signal masts, so that when an engineer comes to a stop signal, he can, after making the stop, readily distinguish between the interlocking and block signals. Later developments in the art have led to further refinements in this particular.

The home and distant signals on separate posts are used in overlap block systems, in single track block systems and in double track block systems where the blocks are unusually long.



Stop Proceed "A" Proceed "B" Proceed "C"

FIG. 9—THREE-ARM, HIGH, TWO-POSITION INTERLOCKED HOME TRACK AND SPEED SIGNALS

MEANINGS

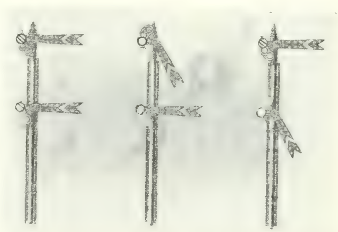
*Stop*—Remain stopped. No routes are ready for train to proceed.

*Proceed "A"*—A high speed route is ready for train to proceed.

*Proceed "B"*—A moderate speed route is ready for train to proceed.

*Proceed "C"*—A low speed route is ready for train to proceed.

Automatic signals are more commonly used on double track roads with heavy traffic and the blocks are short, so that the home and distant signals are frequently mounted on the same post or the equivalent three position signal, shown in Fig. 8, is used.



Caution Proceed "A" Proceed "B"

FIG. 10—TWO-ARM, HIGH, TWO-POSITION INTERLOCKED DISTANT TRACK AND SPEED SIGNALS

MEANINGS

*Caution*—Prepare to stop at next home signal.

*Proceed "A"*—Expect to find next high speed home signal in proceed position.

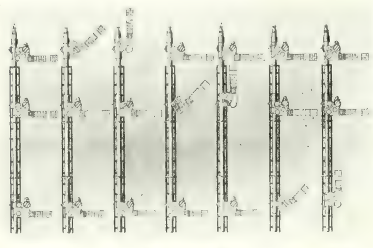
*Proceed "B"*—Expect to find next moderate speed home signal in proceed position.

All of the signals previously described are types in common use. They have not, however, been found adequate for the conditions which have been recently arising. It has been found necessary to increase the capacity of roads by getting the trains over them faster. High speed turnouts and crossovers have been put in, so that this can be accomplished. On one road it is quite common practice to put in a crossover on each side of a sub-

urban passenger station, so that while a local train is making the station stop, an express can come up behind and run around it at a speed of forty miles per hour.

Since many turnouts cannot be taken at even moderately high speeds, a new requirement is that interlocked signals shall also indicate speed as well as tracks and hence the development shown in Fig. 9. These signals require the corresponding distant signals shown in Fig. 10.

A further requirement is that interlocked signals shall also indicate the condition of the block as well as the tracks and speed. This led to the development shown in Fig. 11. At present this is only being used on one road, but is being seriously considered for general adoption by other leading roads. This scheme also provides for a distinguishing feature between automatic block and interlocked signals.

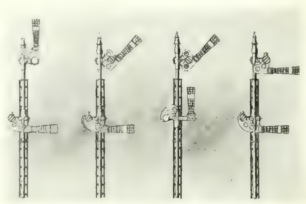


Stop Proceed "A" Proceed "B" Proceed "C" Proceed "D" Proceed "E" Proceed "F"

FIG. 11—THREE-ARM, HIGH, 90 DEGREE UPWARD TRAVEL, THREE-POSITION INTERLOCKED TRACK, SPEED AND BLOCK SIGNALS

MEANINGS

*Stop*—Remain stopped. Route or block not ready for train to proceed.
*Proceed "A"*—Proceed on high speed track. Prepare to stop at next home signal.
*Proceed "B"*—Proceed on high speed track. Expect to find next home signal in proceed position.
*Proceed "C"*—Proceed on moderate speed track. Prepare to stop at next home signal.
*Proceed "D"*—Proceed on moderate speed track. Expect to find next home signal in proceed position.
*Proceed "E"*—Proceed with extreme caution on low speed track.
*Proceed "F"*—Proceed on low speed track.



Proceed "A" Proceed "B" Proceed "C" Stop

FIG. 12—TWO-ARM, HIGH, 90 DEGREE UPWARD TRAVEL, THREE-POSITION AUTOMATIC BLOCK AND INTERLOCKING DISTANT SIGNALS

MEANINGS

*Proceed "A"*—Proceed. Expect to find next high-speed home signal in caution or proceed position.
*Proceed "B"*—Proceed. Prepare to stop at next home signal.
*Proceed "C"*—Proceed. Expect to find next moderate-speed home signal in caution or proceed position.
*Stop*—Stop and wait the prescribed time, then proceed with caution expecting to find train in block, misplaced switch or broken rail.

All interlocked signals have the arms and lights, one vertically below another, while the automatic block signals have the arms and lights staggered as shown in Fig. 12. On approaching an interlocking, the block signals are also used as distant signals for the interlocking home signals. Where the block indication only is given, the lower arm is fixed in the horizontal position and is really only a marker.

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# EXPERIENCE ON THE ROAD

H. W. YOUNG

## SPECIAL APPLICATIONS OF STANDARD TRANSFORMERS

SOME time ago a special application of standard transformers came to the writer's attention and is of sufficient interest to merit a short description.

A company, operating a plant supplying both railway and lighting service, had an opportunity to supply current to a small town located about four miles distant from the company's power house. In order to secure this customer it was necessary for the operating company to supply current within four days of the date of application, as the small local lighting plant of the town had broken down and in view of this the business was offered to the power company on condition that service could be obtained within the time specified. The available source of power was a 360-volt, three-phase, 60-cycle generator supplying current through rotary converters to a railway line and through step-up transformers having 360-volt primaries and 11 000-volt secondaries to a town ten miles distant. Upon inquiry the local manager found that it would require 45 days to secure a transformer with 360 volts primary and 2 200 volts secondary, and 60 days to secure a trans-

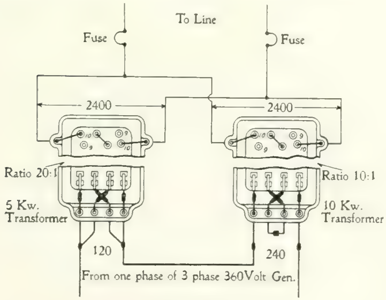


FIG. 1

former having 11 000 volts primary and 2 200 volts secondary. In order to secure the town lighting it was only necessary for the operating company to supply 15 kilowatts at first, which would take care of the lighting of a public building, but even in this small capacity quick delivery of transformers having a special primary of 360 volts, or one having a high tension primary of 11 000 volts appeared to be out of the question.

The problem was easily and quickly solved in the following manner: A standard transformer at 120 volts with a twenty to one ration or 240 volts with a ten to one ratio volts low tension gives 2 400 volts high tension. (These voltages are, of course, considerably higher than normal, although permissible in cases of emergency.) It was seen that 120 + 240 gave 360; that is, if two transformers were used with their high tension windings in parallel for 2 400 volts and their low tension windings in series, one connected for 240 and the other for 120 volts, the group would operate at a ratio of 360 to 2 400 as desired. Therefore, the connections were made on the transformers as indicated in Fig. 1 and diagramatically in Fig. 2. It may be noted that full-load current for the ten kw transformers at 240 volts corresponds to the current of the five kw transformers at 120 volts, thus permitting the operation of the transformers in series on the low tension sides as indicated.

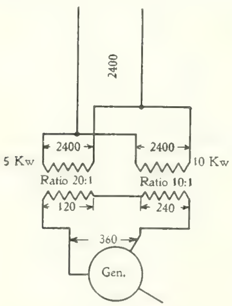

FIG. 2

The ease with which this problem was solved led to the question of how many special applications could be adapted to the regular types of transformers, and the following examples were worked out which may be of service to those called upon to meet similiar emergencies:

*Example I.*—Required 7.5 kw at 500 volts from a 60-cycle, 1 000-volt circuit with standard transformers available. As the high tension voltage of the standard 1 050-volt transformer is substantially that required, and the frequency normal, the problem becomes one of determining a method for obtaining the 500 volts secondary. The 500 volts may be obtained by connecting

two transformers in series, the sum of whose voltages will be that desired, say 400 and 100. If, then, a five kw transformer connected, as shown in Fig. 3, for 1 000 to 400 volts, be used with a 1.5 kw transformer with a ratio of 1 000 to 100, the low tension windings in series will yield 500 volts, and the high tension windings in parallel 1 000 volts, as desired.

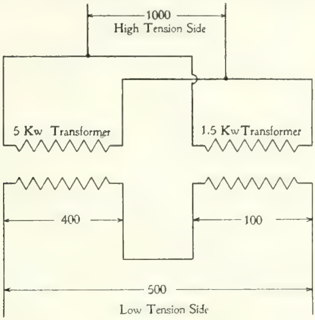

FIG. 3

The current required on the low tension side is 15 amperes ($500 \times 15 = 7.5$ kw) which is the normal current for the 1.5 kw unit, but corresponds to a six kw unit with a 400-volt secondary; that is, the five kw unit will be overloaded 20 percent. That, however, is permissible especially as the iron loss is considerably reduced due to the lower voltage.

Instead of the five kw unit in the foregoing case, two three kw units might be connected at a ratio of 1 000 to 400 with both high tension and low tension windings in parallel and these in turn connected in series on the low tension side with the 1.5 kw above referred to and in parallel on the high tension side.

A further method would be to employ a 15 kw transformer using only the high tension winding. In this case 1 000 volts would be impressed over the high tension winding when 500 volts could be taken from one-half of the winding, as shown in Fig. 4. In this case, however, the 1 000 and the 500-volt circuits are electrically connected. This may or may not be permissible.

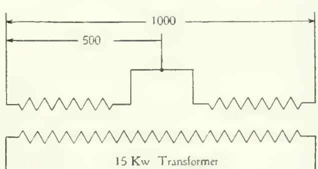

FIG. 4

*Example II.*—Required 250 volts for starting and 400 volts for running a three-phase, 20 hp, 60-cycle motor from a 1 150-volt line. To supply a 20 hp motor will require approximately 20 kw, which, in three transformers, corresponds to approxi-

mately three 7.5 kw units. If these are connected to give a five to one ratio 1 150 volts on the primary will give 230 volts for the secondary. If the transformers are connected with the high tension windings in delta and the low tension windings in star, as shown in Fig. 5, the ratio of the three-phase transformation will be 1 150 to 400 as desired, and by using the middle point of the low tension windings, 200 volts will be available for starting the motor. Usually such motors will start very satisfactorily on one-half voltage.

As another solution, two 15 kw and two three kw transformers may be connected in "V" with one 15 kw and one three kw transformer on each leg, as shown in Fig. 6. With one of the 15 kw transformers connected with a ratio of 2.5 to one, 1 150 volts high tension will give 460 volts low tension. The three kw transformers should then be connected to give a ratio of twenty to one, so that 1 150 volts will give 57.5 volts low tension. If the 15 and the three kw transformers be connected in parallel on the high tension side to the 1 150-volt line and put in series on their low tension windings, so that the three kw transformer winding will oppose that of the 15 kw transformer, the resultant voltage will be 460 minus 57.5 or practically 400 volts. The middle point of the 15 kw low tension transformer gives 230 volts, which is fairly close to that desired for starting the motor.

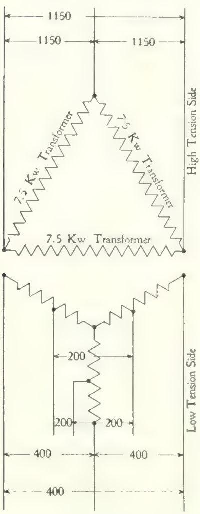


FIG. 5

It may be noted that the normal low tension current of the 15 kw transformer at 400 volts is 37.5 amperes, and 30 amperes for the three kw transformer at 100 volts, so that the current capacities of the transformers are sufficient for the three-phase load of 20 kw at 400 volts, which corresponds to approximately 29 amperes ($20\,000 \div 1.73 \times 400$). Obviously, two 7.5 kw or one ten kw transformer and one five kw transformer might be substituted for the 15 kw transformer and the three kw transformer might be replaced by a four kw, a five kw, or two 1.5 kw transformers, if any of these are more easily available.

INDUCTION METERS ON DIRECT CURRENT

A short time ago a party who had several induction type meters in use reported that his meters had burned out and that he thought there must be some defect in the meters. Inquiry revealed the fact that both alternating and direct-current 110-volt service were furnished by the power plant and that a few days before when a line transformer burned out the direct-current service had been hurriedly connected to the alternating-current secondaries, with the result that a number of the induction meters burned out. The man whose meters had been burned out could not understand why alternating-current meters should burn out under these conditions until it was suggested to him that he connect one of his induction motors to the direct-current service and watch the result.

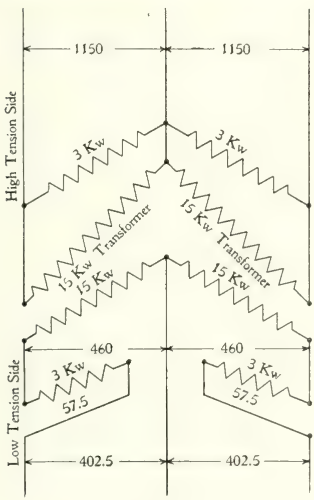


FIG. 6

A GROUND DETECTOR TIED UP

A report was received from a certain central station that the ground detectors on the switchboard would not operate. Along with this news was an urgent request that an expert be sent at once to repair the defective instrument. The expert traveled 400 miles to cut the string which had been tied on the pointer to keep it from swinging during shipment.

# CONTRIBUTORS TO THE JOURNAL FOR 1907

FOLLOWING out the plan inaugurated last year, some notes regarding the contributors to the JOURNAL during 1907 are given herewith. As nearly thirty per cent of the contributors for 1907 also contributed in 1906, their names and present positions only are given. More extended notice may be found in the December, 1906, issue regarding all those before whose name a (*) has been placed.

Practically all of the articles appearing during the present year were prepared especially for the JOURNAL and did not appear elsewhere except as reprints, many of which have appeared in various technical magazines.

A considerable proportion of the contributors are members of The Electric Club, by which the JOURNAL is published.

*C. L. ABBOTT, erection department, Boston district, Electric Company.

C. B. AUEL (Columbia School of Mines, '88-'89; Cornell University, '92, post-graduate '93), after graduation, took the Electric Company's apprenticeship course and was assistant general foreman and manager of the specification and production departments. During 1897-9 he was general manager of the Clarke Brake Company. In 1899 he was appointed electrician and engineer of the Westinghouse Air Brake Company. In 1901 he went to the British Westinghouse Company as assistant to the manager of works and later was made assistant manager of works. In 1905 he returned to the Electric Company as assistant to the manager of works. During the present year his title has been changed to manager of railway department.

*J. R. BIBBINS, technical writer, Westinghouse Machine Company.

B. A. BRENNAN was with the Carnegie Steel Company at their Bessemer works from 1888-91. From 1891 to 1903 he was with the E. P. Allis Company and Allis-Chalmers Company. While at Milwaukee he was one of the founders of the Milwaukee Law Association, now a part of Marqette University. In 1903 he entered the employ of the Westinghouse Machine Company and is now their contract manager. He is the author of "Contracts, Sales and Collections," and "Brennan's Hand-Book" (Legal).

W. H. CADWALLADER has been with the Union Switch and Signal Company for about seventeen years. For about seven years he has been in the specification department and is now signal engineer for that company.

JAMES C. BENNETT has been connected with the Electric Company since about the time of its organization, advancing from various positions which led up to his present position as general auditor.

*WM. COOPER, engineer on control apparatus, railway division, engineering department, Electric Company.

*A. W. COPLEY is engaged with the Electric Company on railway engineering work in connection with problems arising in alternating-current railway systems.

F. DARLINGTON (Pennsylvania State College) was connected with the Electric Company for a short time and then was electrical engineer of the United Electric Light and Power Company operating by alternating-current in New York City. Later he was connected with the Stanley Instrument Company and was then a consulting engineer. For the past few years he has been connected with the Electric Company on general engineering work.

*J. N. DODD, power division, engineering department, Electric Company.

A. M. DUDLEY (Univ. of Michigan, '02), since graduation has filled the following positions: General Electric Company, testing department, 1902-3; erection department, 1903-4; Electric Company, designing engineer on alternating-current controllers and induction motors, 1904-6; industrial engineer on motor applications, 1906-7; Rochester Railway and Light Company, 1907, and at present is in charge of induction motor designs for the Electric Company.

W. K. DUNLAP (Univ. of Rochester, '92) entered the employ of the Electric Company in 1892 as a student. He was connected with the preparation and erection of the switchboard of the Niagara Falls Power Company and later was the Electric Company's resident engineer at Niagara Falls. He was superintendent of construction located at East Pittsburg until the St. Louis Exposition when he was director of Westinghouse Companies' Exhibits. He was subsequently made assistant to the second vice president and then assistant to the first vice president.

W. H. EAGER (Mass. Inst. of Technology, '04) began electrical work in 1893 with the Onondago Dynamo Works, Syracuse, N. Y., where he served in several positions until 1900. In 1904 he entered the apprenticeship department of the Electric Company and later was transferred to the engineering department, where he remained until 1906. At present he is assistant manager of the Chicago works of the Whitman and Barnes Manufacturing Company.

*H. I. EMANUEL, erection engineer, Electric Company.

L. H. FLANDERS (Armour Institute, '98 and '01) was for three years instructor in mechanical engineering at Armour Institute. In 1901 Mr. Flanders became connected with the Westinghouse Machine Company, working first in the gas engine test department and then on special work in connection with storage battery development. Since then he has been devoting special attention to battery work.

A. P. M. FLEMING was educated in England and came to this country and spent several years with the Electric Company, specializing on insulation work, preparatory to continuing this work with the British Westinghouse Company with whom he is now connected.

W. E. FOSTER was formerly with the Pennsylvania Lines, West. For a number of years he has been with the Union Switch and Signal Company, a part of the time at their Chicago office. He is the inventor of a number of forms of signal apparatus. At present he is engineering assistant to the general manager, Union Swith and Signal Company.

CLARENCE P. FOWLER (Univ. of Toronto, '96) entered the Electric Company's apprenticeship course in 1896. Later he was given charge of part of main testing floor and in 1901 was detailed to the New York City office as erection engineer, where he remained for two years. In 1903 he was transferred to the Baltimore office as erection engineer and in 1904 he accepted a position as electrical engineer with Ford, Bacon and Davis. During 1905-6 he was with the Hydro-Electric Power Commission of the Province of Ontario, Canada, as electrical engineer in charge of designs and estimates of stations and local distributing networks and then took his present work as electrical engineer with the Electric Company.

*H. GILLIAM, electrical superintendent, N. Y., N. H. & H. R. R.

CHAS. F. GRAY was educated at Dulwich College, London, England. His subsequent positions are as follows: Sprague Electric Company (shop course), three years on general construction work around New York City and Southern British Columbia; two years at West Kootenay Power and Light Company, Bonnington Falls, British Columbia (operatiton); two years with Interborough Rapid Transit Company, New York City (operation); eighteen months with the Electric Company on construction work and as superintendent of operation, Metropolitan Underground Railway System, London, England. Since May 1 superintendent of construction, Canadian Westinghouse Company.

A. G. GRIER (McGill Univ. '99 and '00), after graduation, held the following positions: Testing room, Royal Electric Company, Montreal; engineering department Stanley Manufacturing Company, Pittsfield, Mass.; assistant to chief engineer, Western Electric Company, Chicago, Ill. At present he is a member of the consulting engineering firm of Westcott and Grier.

F. D. HALLOCK (Lehigh Univ. '94) has held the following positions: As-

sistant engineer and inspector of sewer construction, 1894-95; White Plains Electric Road, in charge of construction; Crocker-Wheeler Company, 1896-7, designing and estimating; Albany Water Filtration System, designing, 1898-9; Electric Vehicle Company, designing and costs, 1899-1901; Electric Company, vehicle motor department, engineer on control apparatus and is at present engineer on rheostats and resistance.

F. W. HARRIS served a three-year apprenticeship with the Belknap Motor Company, Portland, Maine. He left their employ to act as draftsman for the Maine Electric Company, being employed there one year. In 1900 he entered the office of Heyl and Patterson, contracting engineers, where he gained considerable experience in motor applications and control in the mills of the Pittsburg district as well as general experience in mechanical and structural design. In 1903 he came to the Electric Company, entering the detail engineering department, where he took up railway details, car layout work, etc. He later became head of the information division, having charge of production work in the engineering department. At present he is section engineer on circuit breakers, fuses, etc.

*DEAN HARVEY, insulation engineer, detail and supply division, enginering department, Electric Company.

J. S. HOBSON, assistant general manager, Union Switch and Signal Company.

*L. FREDERICK HOWARD (Mass. Inst. of Technology, '95) was employed in the U. S. Lighthouse department until 1899, when he took up power station work in the electrical engineering office of the Boston Elevated Railroad. Later he was transferred to the signal department where he remained until 1905, when he accepted his present position as electrical engineer of the Union Switch and Signal Company.

R. B. INGRAM, after serving eighteen months' apprenticeship in a machine shop, entered the apprenticeship course of the Electric Company in 1898. In 1900 he was transferred to the engineering department, his work being in connection with the development of high tension apparatus. In 1903 he became assistant engineer on protective apparatus and is still engaged in this work.

*R. P. JACKSON, engineer on protective apparatus, detail and supply division, engineering department, Electric Company.

VLADIMIR KARAPETOFF (C. E. Institute of Ways of Communication, Russia, '97), Russian government engineer, 1897-9. Assistant to professor of hydraulics and electrical engineering, Ways of Communication Institute, 1897-99. Student in Electric-Technical Institute at Darmstadt and short apprenticeship courses in construction work with the Laymayer Electric Company, and the Algemeine Electricitats Gesellschaft, 1899-1900. Russian government engineer and instructor of electrical engineering at the following institutions: (a) Ways of Communication; (b) Electro-Technical; (c) Polytechnic Institute of St. Petersburg, 1900-2. Conducted evening classes in experimental physics and mechanics in a free school of St. Petersburg, 1898-1901 (Winters). Assistant professorship, Institute Ways of Communication, 1902. Apprenticeship course with the Electric Company, 1903-4. He at present is assistant professor of experimental electrical engineering at Cornell University.

*WALTER C. KERR, president, Westinghouse, Church, Kerr & Company, New York City.

*ALBERT KINGSBURY, mechanical engineer, power division, engineering department, Electric Company.

*H. L. KIRKER, erection engineer for the Electric Company, at present in charge of the electrification of the Sarnia Tunnel.

J. HENRY KLINCK (Lehigh, '99, Cornell, '04), after the termination of his instructorship at Lehigh, became interested in the magnetic concentration of iron ore. Later he was electrical engineer for the Lehigh Valley Railroad. His present position is that of commercial engineer in the industrial and power department of the Electric Company in connection with the equipment of railroad shops.

P. H. KNIGHT (Cornell, '92) took the apprenticeship course at the Electric Company and was on erection work during 1892-97; he was with the Utah Power Company from 1897-1900. In 1901 he became district engineer for the Electric Company at San Francisco and during 1902 was with the Snoqualmie Falls Power Company, Seattle, Wash. Mr. Knight is now in the engineering department of the Electric Company in

connection with the supply of raw material.

PHILIP A. LANGE became associated with the Electric Company about 1886, having previously been employed by the Bergman Company in New York in the manufacture of electric instruments. For a number of years he had charge of the manufacture of instruments and detail apparatus and had charge of the Newark works from 1891 to 1894. He then became superintendent and later, manager of works at E. Pittsburg until about two years ago, when he became associated with the British Westinghouse Company. He is now their general manager of works.

J. E. LATTA (Univ. of North Carolina, '99, Harvard, '04), while a student at the university, managed the plant supplying the town and the university with light and power, being regularly one of the men in charge of the plant. After graduation he remained at the university two years as instructor in physics. He then went to Harvard, where he studied both in Harvard College and in the Lawrence Scientific School. In 1904 he was elected manager of the Durham Traction Company, but resigned before entering upon his duties, in order to become associate professor of physics and electrical engineering in the University of North Carolina, which position he now holds. In his summer vacation Mr. Latta has done work at Cornell and in the Pittsburg factories of the Electric Company.

*P. M. LINCOLN, engineer of power division, engineering department, Electric Company.

*W. M. McFARLAND, acting vice president, Electric Company.

*PAUL MacGAHAN, meter engineer, detail and supply division, engineering department, Electric Company.

MALCOLM MacLAREN (Princeton, '90, '92 and '93) was engaged in testing and designing for the Electric Company from 1893-97. From 1897-1901 he was with the British Westinghouse Company on commercial and engineering work and from 1901-5 was their chief electrical engineer. At present he is at the head of the railway project division of the engineering department of the Electric Company.

RALPH D. MERSHON (Ohio State Univ., '90), consulting engineer, New York City; was engaged in engineering work for the Electric Company for several years. He installed the plant of the Colorado Electric Power Company and conducted important tests on losses in high tension transmission circuits at Telluride in 1897. As a consulting engineer his specialty is high-tension transmission. He has been chairman of the high tension committee of the American Institute of Electrical Engineers.

H. F. MILLER entered the employ of the Electric Company in 1889, first in the tool, lathe and press department and was then for several years with the controller department. He spent one year with the erecting department and then was appointed assistant in testing of instruments and switchboard details, inspector, foreman of testing and assembling, and for the past three years assistant superintendent of manufacture at the Newark works of the Electric Company.

C. B. MILLS has been connected with the Rider-Ericsson Engine Company, the Bullock Electric Company, and in 1889 he came to the Electric Company as a draughtsman. Since 1904 Mr. Mills has been in the engineering department in the capacity of mechanical engineer of industrial apparatus.

WM. O. MILTON (University of Pennsylvania, '02 and '04) was for some time in the department of steam engineering of the Cambria Steel Company. Later he was in the engineering department of the Electric Company on detail apparatus; at present he is employed at the air compressor plant of the Chicago Pneumatic Tool Company at Franklin, Pa.

WILLIAM NESBIT was for two years electrician for the Central Electric and Foundry Company of Lewisburg, Pa. During 1897-8 he took the apprenticeship course of the Electric Company. From 1899-1900 he was engineer on transformer design and from 1900-3 he was engineering salesman at Syracuse and since 1904 has been at the New York office.

*F. D. NEWBURY, engineer on alternating-current machinery, power division, engineering department, Electric Company.

E. R. NORRIS was with John Wiley and Sons during 1888-9, after which he took a three-year mechanical apprenticeship at the Brooks Locomotive works, Dunkirk, New York, and at the same time attended a night school maintained by the company. He entered the erecting

department of the Worthington Pump works in 1892. He was assistant foreman in the Newark works of the Electric Company in 1892, and later went to the East Pittsburg works where he was successively section foreman and acting foreman railway motor department, general foreman induction motor section and is at present assistant superintendent in charge of rate departmnet.

JOHN C. PARKER (Univ. of Michigan, '01, '02 and '04), after leaving college, was employed by the General Electric Company in the testing department; taught under Professor Steinmetz at Union College; acted as assistant superintendent to the engineer in charge of the Ontario Power Company's hydraulic development at Niagara Falls; assistant to chief engineer of the Iroquois Construction Company building lines of the Niagara, Lockport and Ontario Power Company; mechanical and electrical engineer for F. B. H. Paine, and at present is mechanical and electrical engineer with the Rochester Railway and Light Company on general engineering, investigation and construction work.

T. H. PATENALL is a native of England and was employed by a number of signal companies before coming to this country, among them the Saxeby and Farmer Company. He came from England about twenty years ago and was with the old Union Company for about two years, after which he was with a number of signal companies, such as the Johnston and the National Railway Signal Company. He is the originator of a number of patents on the train staff system and has done much to develop this system. He has been with the Union Switch and Signal Company for the last ten years and is at present signal engineer for that company.

*J. S. PECK, consulting electrical engineer, British Westinghouse Company.

L. T. PECK (Ohio State Univ.) has been connected with the Electric Company in various departments since 1901 when he entered the apprenticeship course. He is now assistant in charge of the power correspondence department.

*T. S. PERKINS, engineer of detail and supply division, engineering department, Electric Company.

RALPH W. POPE entered the service of the Housatonic Railroad in 1859. In 1861 he was with the American Telegraph Company; in 1865 with the Collins Overland Telegraph, British Columbia; in 1867 with the Bankers and Brokers Telegraph Company; in 1873 with the Gold and Stock Telegraph Company, and in 1882 with the Union Electric Manufacturing Company. In 1885 he became associate editor of the Electrician and Electrical Engineer. Since 1885 he has been secretary of the American Institute of Electrical Engineers.

CHAS. H. PORTER (Brown Univ., '00, Mass. Inst. of Technology, '03) was with the Chase-Shawmut Company for a year and then returned to the Institute as assistant instructor in electrical engineering, his present position.

*H. G. PROUT, vice president and general manager, Union Switch and Signal Company.

C. G. RALSTON (Cincinnati Technical School, '97), after spending a short time with the Jantz and Leist Electric Company, entered the employ of the Triumph Electric Company, where he was engaged in various lines of work for a number of years. He was also with the Jenney Electrical Company for a short time. He then was electrician of the Pugh Power Building until about two years ago, when he took up his present work as chief electrician at the LeBlond Machine Tool works.

K. C. RANDALL (Univ. of Nebraska, '95) remained two years after graduation at the University of Nebraska as an instructor, after which he was engineer for a company operating water power plants for the generation of electricity and the manufacture of ice in Salvador, Central America. After over a year in the tropics Mr. Randall's health failed and he returned to the United States to enter the employ of the Electric Company, where for the past eight years he has specialized in transformer work and since 1904 has been in charge of the transformer division of the engineering department.

CLARENCE RENSHAW (Mass. Inst. of Technology, '99) came to the Electric Company in 1899 where he conducted special investigations relative to split-phase motor patents. He has assisted Mr. B. G. Lamme during development of the single-phase railway system. He is at present engaged on project and equipment work in connection with single-phase systems.

GEORGE I. RHODES (Mass. Inst.

of Technology, '05) entered the employ of the Rockingham County Light and Power Company of Portsmouth, N. H., and in 1905 became assistant in electrical engineering at the Massachusetts Institute of Technology. Since 1906 he has been assistant engineer for the Interborough Rapid Transit Company.

B. P. ROWE (Cornell, '92), after graduation, was connected with the Short Electric Railway Company as erecting engineer and about a year later went into the employ of the General Electric Company as road engineer. About a year was then spent with a gold mining company of Sonora, Mexico. He then went with the Electric Company as road engineer, and in 1895 as switchboard engineer in development and standardization work. In 1906 was appointed to his present position of engineer in charge of switchboard work.

H. V. RUGG, entered the employ of the Electric Company in 1894 and after spending three years on general shop work, entered the testing department, and five years later was transferred to the New York office of the erecting department, where he remained for three years. In 1905 Mr. Rugg was made district engineer of the Philadelphia district.

*M. C. RYPINSKI, meter expert, detail and supply division, engineering department, Electric Company.

H. M. SCHEIBE (Toronto Univ., '04) completed a fellowship in the electrical department at Toronto University. One and one-half year's general experience was obtained before entering the apprenticeship course of the Electric Company. After one year of experimental work on fan motors, Mr. Scheibe has turned his attention to mercury arc rectifier work.

*CHAS. F. SCOTT, consulting engineer, Electric Company.

GEORGE C. SHAAD (Penna. State College, '00) entered the testing department of the General Electic Company at Schenectady in 1900 and later was in the draughting rooms and engineering office. In 1902 he became an instructor in the electrical engineering department of the University of Wisconsin. At present he is associate professor of electrical engineering at the Massachusetts Institute of Technology.

V. W. SHEAR (Case School of Applied Science, '06) entered the employ of the Electric Company in 1899, and while continuing school and college work, has devoted his time during vacation periods to work with this company. The time thus spent in shop and office amounted to nearly five years. After graduation nine months were spent in the testing department, and since then Mr. Shear has been connected with the correspondence department on lighting and contract work.

H. D. SHUTE (Mass. Inst. of Technology) has been connected with various departments of the Electric Company and has advanced through the engineering and correspondence departments to his present position as assistant to second vice president.

*S. L. SINCLAIR, erection engineer, Electric Company, New York district.

*C. E. SKINNER, division engineer, research division, engineering department, Electric Company.

*EDWARD H. SNIFFIN, vice president and sales manager, Westinghouse Machine Company.

C. E. STEPHENS (Ferris Institute, Ferris, Texas, '00) took the Electric Company's apprenticeship course during 1902-4. From 1904-6 he was engaged on mould design and as insulation engineer. At present he is arc lamp engineer.

EDMUND C. STONE (Harvard Univ., '04), after completing the apprenticeship course of the Electric Company, took up transformer work in the engineering department, in which work he is now engaged.

*H. G. STOTT, superintendent of motive power, Interborough Rapid Transit Company, New York City; president, American Institute of Electrical Engineers.

J. B. STRUBLE (Penna. State College, '89) has been with the Union Switch and Signal Company from 1889 to the present time. After having had a general experience in the office and shops at Swissvale, he was transferred to construction work on the road, and later had charge of the construction of a number of important electro-pneumatic interlocking and block signal plants. He originated, invented and assisted in the development of the system to control railway signals by alternating current. He had charge (in 1903) of the first installation of this kind and is now on the engineering staff at Swissvale.

*H. B. TAYLOR, with Hadaway

Electric Heating and Engineering Company.

J. D. TAYLOR was engaged in signal work as early as 1891, when he took out some patents on interlocking. He continued to work out further improvements and in 1900 sold all his signal patents to a company known as the Taylor Signal Company, of Buffalo, and remained with the company for four years. Later this company combined to form the General Railway Signal Company. He came to the Union Switch and Signal Company in 1904 for the purpose of developing electric interlocking and is at present their assistant electrical engineer.

*PERCY H. THOMAS, of the firm of Thomas and Neall, consulting engineers, New York and Boston.

*W. H. THOMPSON, electrical engineer, American Telegraphone Company, Wheeling, W. Va.

L. H. THULLEN, formerly with the Union Switch and Signal Company.

H. W. TURNER was with the old Weston Electric Company in 1881-2, and later with the Thomson-Houston Electric Company in various capacities. In 1892 he became chief of winding department of the Union Electricitats Gessellschaft, Berlin, Germany. He was specialist on insulation and winding for the British Thomson-Houston Company in 1903. At present he is a member of the firm of Hobart and Turner, consulting engineers, London, England.

E. D. TYREE (Technical education with International Correspondence Schools) was for ten years operating engineer of the Richmond Railway and Electric Company. During 1900 to 1903 he was in the erection department of the Electric Company at the Philadelphia office, and during 1903-4 at the St. Louis office. During the last two years he has had charge of erection work at the Southern Power Company. At present he is with Mr. Gilliam, electrical superintendent, N. Y., N. H. & H. R. R.

MILES WALKER (Cambridge Univ.) was at one time assistant to Sylvanus P. Thompson. He spent several years with the Electric Company in Pittsburg and returned to England as designing engineer of the British Westinghouse Company.

T. GEORGE WILLSON entered the employ of the Union Switch and Signal Company in 1898 as tracer in the drafting room. He is at present in charge of the interlocking department with the title of interlocking engineer.

N. J. WILSON (Taunton College, Somerset, England), after taking several engineering courses at different English schools, entered the employ of the Electric Construction Company first as a student and later for four years as electrical engineer at their Bushbury works. He then was with the British Westinghouse Company and also with the Electric Company at Pittsburg studying American methods. He was for some time head of the testing department of the British Westinghouse Company. He is now a consulting engineer at Liverpool, England.

CHAS. I. YOUNG (Princeton, '83) was employed by the Edison Machine works, New York, testing generators during 1884-5. His respective positions then were: Superintendent of the Edison Electric Illuminating Company, Newbury; engaged by the Westinghouse interests in fall of 1886 and sent to operate a plant at Trenton, N. J., on direct-current three-wire Byllesby system; in 1887 he was employed as road engineer in erecting and starting plants and looking after trouble cases. In 1888 he received a 2 500-volt shock. This, followed by malaria fever in New Orleans, necessitated Mr. Young's retirement until December, 1891, when he returned to Pittsburg. Since then his work has been chiefly along the lines of commercial engineering at Pittsburg up to the fall of 1895, and then in connectiton with sales offices of the Electric Company as follows: Philadelphia, 1895 to 1901; New York Export to 1904. During 1904 and 1905 Mr. Young devoted his time to work in connection with the JOURNAL and The Electric Club and then returned to the Philadelphia office of the Electric Company on engineering work.

H. W. YOUNG gained his early experience with the Whitney Electrical Instrument Company, followed by several years' experience in the factory, engineering and commercial departments of the General Electric Company. For the past three years he has been connected with the sales organization of the Electric Company and is at present special representative of the detail and supply department of that Company. Mr. Young is a frequent contributor to the various electrical journals.

# FOUR YEAR TOPICAL INDEX

OF

# THE ELECTRIC JOURNAL

(VOL. I, No. I, TO VOL. II, No. 6, THE ELECTRIC CLUB JOURNAL)

WITH

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The index is arranged according to the "Topical Classification of Electrical and Railway Engineering References," published in the February, 1906, issue of THE ELECTRIC JOURNAL.

The references do not necessarily bear the authors' titles of the articles, but aim rather to give good conceptions of the subject matters. The authors' names and short descriptions follow; further characteristics are abbreviated by the letters, T-Number of tables; C-Number of curves; D-Number of diagrams; I-Number of illustrations; W-Number of words.

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(4) Approximate practical diagram; (5) experimental determination of inductive resistance of a transformer; (6) Kapp's diagram for pre-determination of drop and regulation; (7) diagram of auto-transformer. Explanation; diagrams; examples. D-8, W-2200. Vol. I, p. 410, Aug., '04.

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**A Chart for Use in Magnet Designing**—L. F. Howard. D-1, W-1200. Vol. III, p. 408, July, '06.

# GENERATION

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**Northern California Power Co.**—G. W. Appler. Troubles; dirt in penstock; prevention; maintaining service; telephone line on power line poles. D-2, W-1000. Vol. II, p. 576, Sept. '05.

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**Regulation in Mercury Vapor Converters**—Percy H. Thomas. I-2, W-800. Vol. III, p. 345, June, '06.

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# TRANSMISSION

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**Single-Phase Railway System — Westinghouse** — Clarence Renshaw. Comprehensive article on generating and distributing system; apparatus. C-1, D-7, I-3, W-5000. Vol. I, p. 133, Apr., '04.

**Single-Phase Synchronous Transmission.** The Telluride Plant, early experience and description of apparatus. (E) Chas. F. Scott, p. 519. I-5, W-800. Vol. II, p. 504, Aug., '05.

**Transmission Troubles, High Voltage, Hydraulic**—G. W. Appler, Northern Cal. Power Co. Troubles due to dirt and refuse in supply pipes to plant; scheme to overcome same. Transmission troubles; prevention. Successful telephone line construction on power poles. D-2, W-1000. Vol. II, p. 576, Sept., '05.

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